

Minerals and Energy Branch  
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## Geology of the South Mountain Batholith, Southwestern Nova Scotia

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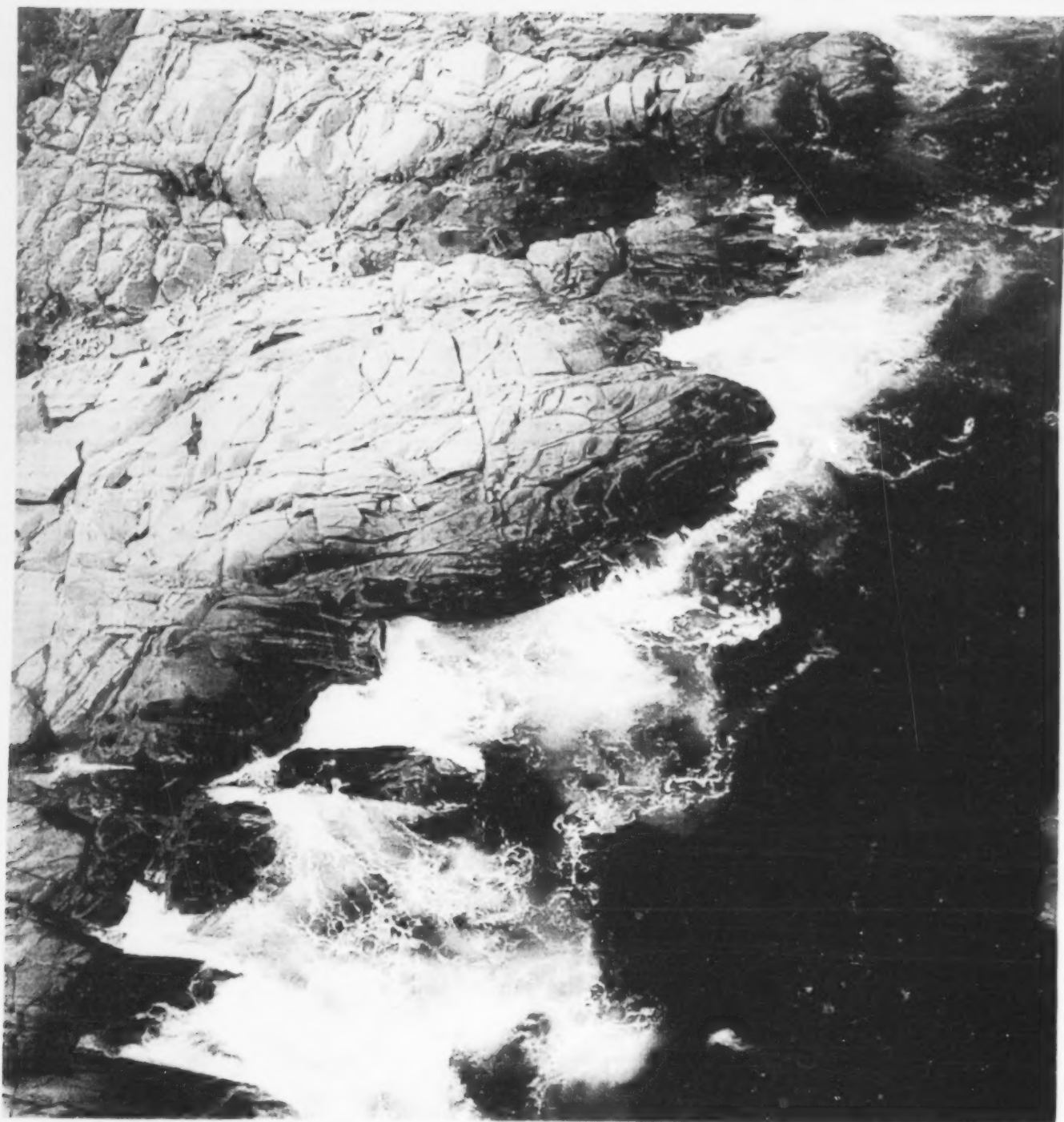


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Coastal exposure of Harrietsfield muscovite-biotite monzogranite at Chebucto Head, south of Halifax  
(Photo by Reg Morrison, DNR)

## PREFACE

The South Mountain Batholith of southwestern Nova Scotia is the largest granitoid batholith in the Appalachian Orogen with an approximate area of 7300 km<sup>2</sup>. The batholith has been the focus of numerous studies commencing with mapping and mineral exploration around the turn of the century and continuing with extensive mineral exploration, geochemical and petrological studies to the present. Geological mapping has ranged from detailed studies in localized areas to reconnaissance surveys of portions of the batholith. The South Mountain Batholith project was conducted by the Department of Natural Resources as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement and represented the first comprehensive mapping programme for the entire granite body. The chief goal of the project was to gain insight into the mineral potential of the batholith, particularly in light of the discovery of the East Kemptville polymetallic-Sn deposit and the Millet Brook U-Cu-Ag deposit in the late 1970's and early 1980's. This report is a direct result of the mapping and follow-up studies that were conducted by M.C. Corey, L.J. Ham, R.J. Horne and the author during the project.

The report is accompanied by a 1:250,000 scale multi-coloured compilation map (Nova Scotia Department of Natural Resources Map 94-01).

*This Report is Dedicated to the Memory of*

*J. Stackhouse who lost his life while working as a geologist in 1977.*

*He is missed.*

## ABSTRACT

Geological mapping of the South Mountain Batholith of southwestern Nova Scotia was conducted as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement. A rock classification scheme was developed for subdividing granitic rocks. The scheme combined the relative proportions of quartz-alkali feldspar-plagioclase, modal proportions of biotite ( $\pm$ cordierite $\pm$ garnet) and muscovite, grain size and texture. Seven main rock types were established using this scheme, including (in decreasing order of mafic mineral content): mafic porphyry, biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite and muscovite $\pm$ topaz leucogranite.

A total of 260 discrete granite map bodies were delineated in the batholith. These bodies were grouped into 49 map units based on field relationships and composition. Each map unit was assigned a prominent place name or geographical feature and a rock name (e.g. East Kemptville leucogranite).

The 49 map units were assigned to 13 plutons, based on field relationships and compositional variations. Five plutons are classed as early Stage I, comprising biotite granodiorite and biotite monzogranite with minor fine-grained leucomonzogranite. These were the first plutons to be emplaced. Stage I plutons were intruded by a series of eight Stage II plutons, comprising muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite and muscovite leucogranite with minor biotite granodiorite and biotite monzogranite.

Contacts between Stage I and II plutons are not well exposed but, where observed, are mostly intrusive. Contacts between the coarser grained megacrystic units in Stage II plutons are mostly intrusive, but some were noted to be gradational. Contacts between biotite monzogranite and biotite granodiorite in Stage I plutons were noted to be both intrusive and gradational. Late-staged fine-grained leucomonzogranite and leucogranite mostly intrude the megacrystic units with the exception of a few porphyry bodies in the New Ross Pluton that are in gradational contact with the megacrystic leucomonzogranite and represent textural variations of the host.

Detailed petrographic studies of the six main rock types indicate that rocks of the various plutons have similar mineralogical characteristics. For example, the presence of biotite, muscovite, aluminosilicate (e.g. andalusite), cordierite, garnet and tourmaline, in virtually all of the plutons, is consistent with the "characteristic" mineral assemblage for peraluminous granites. Biotite decreases in abundance from approximately 25% in biotite granodiorite to  $<0.1\%$  in some muscovite leucogranite bodies. In contrast muscovite increases in the same rock sequence from trace amounts in granodiorite to 28% in some leucogranites. Topaz is absent in all rocks except some leucogranites (e.g.  $\leq 8\%$  in the East Kemptville leucogranite). Cordierite is a minor constituent in most rocks but may constitute up to 5% of the mode in some muscovite-biotite monzogranite and coarse-grained leucomonzogranite units. Garnet is present in trace amounts in many rock units but is most abundant in late-staged leucomonzogranite dykes. Hornblende has not been observed in any of the rocks of the batholith. The only occurrence of magnetite in the entire batholith is in a single hydrothermally altered sample of albite-magnetite breccia from a drill hole near the East Kemptville deposit. The ubiquitous occurrence of accessory ilmenite, along with muscovite and low Mg/Fe biotite, is consistent with the "ilmenite-series" granitoids.

Detailed investigations indicate that although most major rock-forming mineral phases are of magmatic origin, many minerals also formed by xenocrystic, hyperaluminous or metasomatic processes at various stages in the evolution of the batholith. Therefore the exact origin of a mineral phase in any given rock must be evaluated individually.

In spite of the overall textural and mineralogical similarities throughout the batholith, several plutons display unique petrographic features. For example, the ubiquitous metasomatic garnet (reaction relationship with biotite) in both the fine- and coarse-grained leucomonzogranite rocks of the Big Indian Lake pluton is rare to absent in the other twelve plutons. Similarly, trace amounts of secondary, metasomatic sillimanite (mostly fibrolite) are unique to the Big Indian Lake pluton. Accessory titanite and epidote occur as inclusions, along with zircon, apatite, monazite and ilmenite, in biotite of the Davis Lake pluton and a cumulate phase from the Big Indian Lake pluton. Neither titanite nor epidote has been reported in any of the other eleven plutons. These mineralogical features suggest that different physico-chemical conditions ( $T$ ,  $P_{H_2O}$ ,  $fO_2$ , bulk composition) prevailed in the various plutons.

A set of 597 samples, representing the complete compositional range for the batholith, was analyzed for major elements and a suite of 21 trace elements. Perhaps the most striking feature of the geochemistry of the batholith is the overall similarity in composition throughout the batholith. All rocks are peraluminous (i.e. molecular  $Al_2O_3/(CaO+K_2O+Na_2O) > 1$ ) and have relatively high  $SiO_2$  and low  $CaO$  with ranges from 67.12% (SD-1.73) and 1.94% (SD-0.46), respectively, in granodiorite to 73.62% (SD-0.89) and 0.39 (SD-0.14), respectively, in leucogranite rocks. The major element chemistry and normative composition of the major rock types indicate a sequence from least evolved biotite granodiorite to most evolved leucogranite that reflects the petrographic features of the different rock types. This sequence is marked by systematic decreases in  $TiO_2$ ,  $Fe_2O_3$ ,  $MnO$ ,  $MgO$ ,  $CaO$ ,  $K/Rb$  and normative anorthite, enstatite, ilmenite, hematite, rutile and colour index and increases in  $SiO_2$ , normative quartz,  $A/CNK$  and Thornton-Tuttle differentiation index. The concentration of  $P_2O_5$  is generally consistent from granodiorite to fine-grained leucomonzogranite with a sudden increase in leucogranite units. This sequence is also marked by systematic decreases in several compatible trace elements (i.e. Ba, Sr, Zr, V, Hf, Sc and La) and increases in several incompatible trace elements (i.e. Rb, Ta, U, Li, F, Sn and W).

Despite the overall compositional similarities throughout the batholith, it is possible to distinguish among individual plutons. This implies that the batholith probably constitutes numerous discrete plutons that coalesced to form a contiguous batholith, in contrast to earlier studies that proposed the entire batholith formed from a single parental magma.

Perhaps one of the most important implications of the geochemical data is the delineation of cryptic normal and reverse compositional zoning in both Stage I and II plutons.

In spite of a definitive sequence of emplacement for the plutons and their units, an evaluation of published geochronological data indicates that all plutons were intruded and crystallized during a very short time interval (<5 million years) at 370 Ma.

Various structural characteristics, including the shape and distribution of plutons, the coincidence of several Stage II plutons with major fault zones, and the orientation of primary and secondary structural features (e.g. megacryst alignment, joints, veins), indicate that the batholith was subject to regional stresses associated with the waning stages of the Acadian Orogeny.

Mineral occurrences can be classed into five types including: greisen-type (e.g. East Kemptville); vein-type (e.g. New Ross Mn Mines; Millet Brook); breccia-type (e.g. Tobeatic Shear Zone); pegmatite-type (e.g. several occurrences in the New Ross Pluton); and peribatholithic (e.g. the Duck Pond Sn deposit). Similarly, the style of mineralization in the sundry plutons is interpreted as reflecting the protolith composition and the physico-chemical conditions that prevailed during their crystallization. Accordingly, the economic potential of the 13 plutons must be evaluated individually.



## ACKNOWLEDGMENTS

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## *Chapter 1*

### OVERVIEW

#### 1.1 Introduction

The South Mountain Batholith is an arcuate composite granitoid batholith that outcrops in southwestern Nova Scotia. The batholith, which extends from the city of Halifax to near Yarmouth, occupies an area of approximately 7300 km<sup>2</sup> and is the largest granitoid body in the entire Appalachian Orogen of eastern North America. The batholith is bounded by Latitudes 44°00' and 45°00' and Longitudes 63°30' and 66°00' and outcrops in portions of Halifax, Hants, Lunenburg, Kings, Queens, Annapolis, Digby, Yarmouth and Shelburne Counties (Fig. 1.1).

The batholith was the target of sporadic mineral exploration activity from the late 1800's to present. The largest exploration "boom", which occurred between the middle 1970's and the early 1980's, led to the discovery of the East Kemptville Mine (Sn-Zn-Cu-Ag; Richardson et al., 1982) northeast of Yarmouth, and the Millet Brook deposit (U-Cu-Ag; Chatterjee et al., 1985), south of Windsor (Fig. 1.1). The chief catalyst for this exploration "pulse" was the recognition that the batholith and, in fact, most of the granitoid bodies of the Meguma Zone are similar in composition to the granitoid bodies of worldwide "tin belts". In particular the batholith closely resembles Hercynian-aged granites in the Cornwall district of England and the Massif Central area of France. These areas are host to numerous "gregarious" Sn-W-U-Mo deposits and subsequently the discovery of the East Kemptville and Millet Brook deposits was considered to be merely the "tip of the iceberg" (Giles and Chatterjee, 1984).

In spite of the extensive exploration activity, the geological map of the batholith, prior to the commencement of this project (Keppie, 1979), was principally based on reconnaissance mapping by McKenzie (1974) and Smith (1974). Therefore, the South Mountain Batholith project was initiated by the Nova Scotia Department Natural Resources as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement. The primary objectives of the project were to produce detailed (1:50,000 scale) geological maps for the entire batholith and surrounding country rock/cover rock sequences and to conduct follow-up petrographic, geochemical and mineral deposit studies of specific aspects of the granitoid rocks where deemed necessary. This information would subsequently be used to evaluate the overall

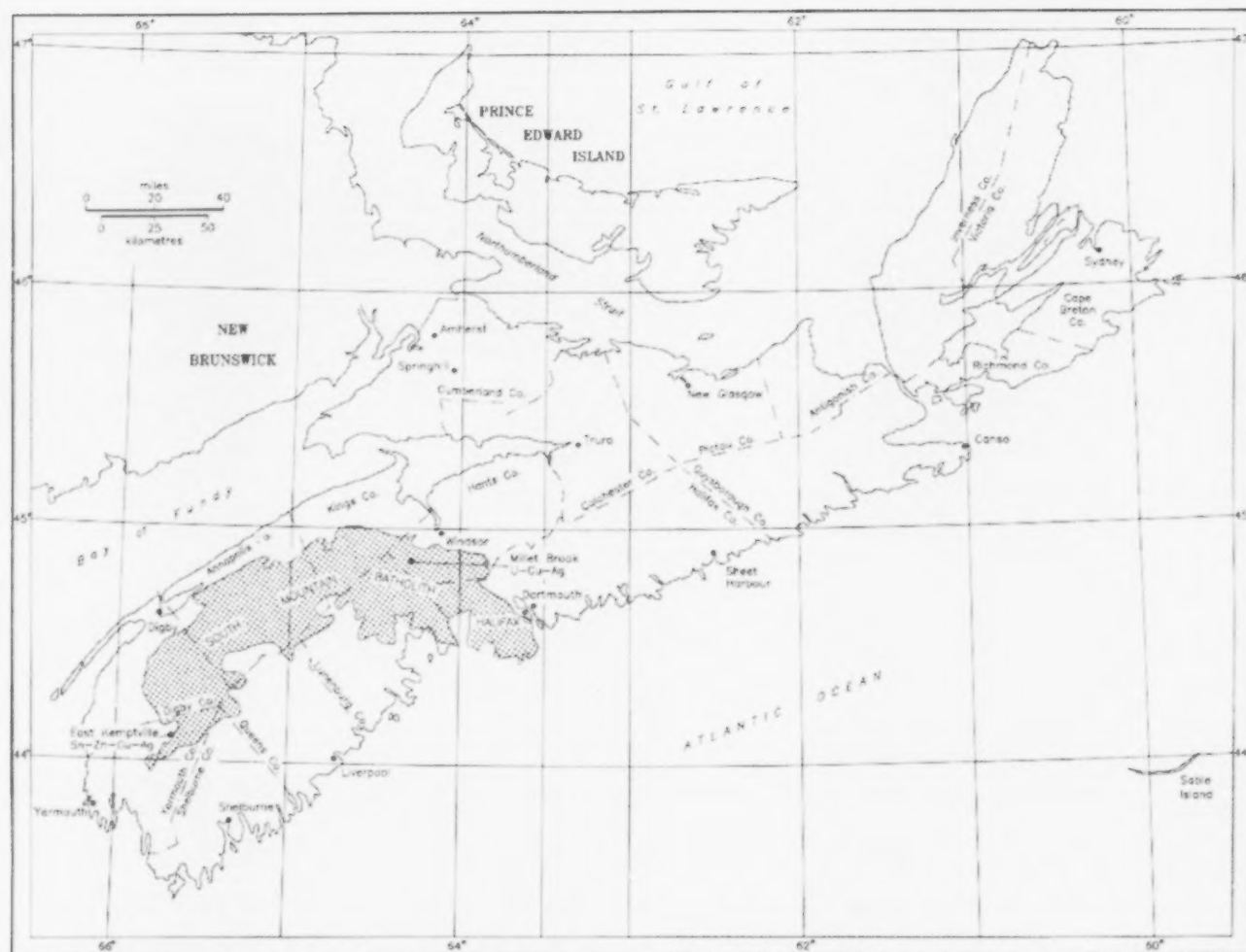


**Figure 1.1** Location map for the South Mountain Batholith showing the county boundaries for southwestern Nova Scotia and the location of the East Kemptville and Millet Brook deposits.

economic potential of the batholith. Geological mapping began in 1984 with a detailed investigation of the textural diversity of rocks along a section of highway between Halifax and Chester (MacDonald, 1985). Detailed mapping of the entire batholith commenced in 1985 and was completed in 1988.

The purpose of this report is to present a comprehensive summary of the mapping methodology, petrographic nomenclature and the organization of rock units and results of field mapping from the South Mountain Batholith project. The report also presents summaries of new and published information pertaining to various geological aspects of the batholith including: petrology, geochemistry, structural geology, mode of emplacement, time of

emplacement and crystallization, economic geology and exploration methodologies. In addition, a 1:250,000 scale coloured compilation map outlining the geology of the batholith is included (NSDNR Map 94-01, in pocket in back).

## 1.2 Regional Geological Setting

The South Mountain Batholith is located within the Meguma Terrane (Fig. 1.2), a suspect terrane of the Appalachian Orogen (Williams and Hatcher, 1983). Pre-granitic rocks in the Meguma Terrane include the Cambro-Ordovician Meguma Group and overlying Siluro-Devonian (Emsian) White Rock and Torbrook Formations (Taylor, 1969). The former is comprised of Goldenville Formation psammities and conformably overlying Halifax Formation pelites, whereas the latter comprises mixed volcanic rocks, volcanoclastic and metasedimentary rocks. These rocks were regionally metamorphosed and deformed during the Mid- to Late Devonian Acadian Orogeny (Keppie and Dallmeyer, 1987; Muecke et al., 1988). Following the regional deformation and metamorphism, numerous meta- and peraluminous granitic intrusions, including the South Mountain Batholith, were emplaced ca. 370 Ma (Fairbairn et al., 1964; Clarke and Halliday, 1980; Reynolds et al., 1981, 1987). The batholith is overlain by coarse clastic terrestrial sedimentary rocks of the Horton Group of Tournaisian age (Bell and Blenkinsop, 1960; Howie and Barss, 1975; Utting et al., 1989) to Late Devonian age (Boehner and Giles, 1993). Thus, the times of intrusion, crystallization and unroofing are restricted to a very narrow interval between the Emsian and early Tournaisian periods.

Recent work in the eastern Meguma Terrane now provides insight into its crustal stratigraphy at ca. 370 Ma. Giles and Chatterjee (1986, 1987) reported an orthogneiss and paragneiss complex with associated gabbroic intrusions that pierced the Meguma Group metasedimentary rocks near Liscomb. Geochronological studies ( $^{40}\text{Ar}/^{39}\text{Ar}$ ) of the gneissic rocks (Kontak et al., 1990) indicate that they were emplaced in the waning stages of the Acadian Orogeny (ca. 370 Ma) along with the major granitoid plutons. Clarke et al. (1993) concluded, on the basis of detailed petrographic and geochemical studies, that the Liscomb gneisses are chemically distinct from the Meguma Group rocks and represent a sample of the lower crust.

Ruffman and Greenough (1990) reported a mafic dyke swarm, termed the "Weekend dykes", that outcrop in the eastern Meguma Terrane (Fig. 1.2). They noted that approximately half of the dykes contained exotic gneissic and (meta)plutonic xenoliths. Kempster et al. (1989)

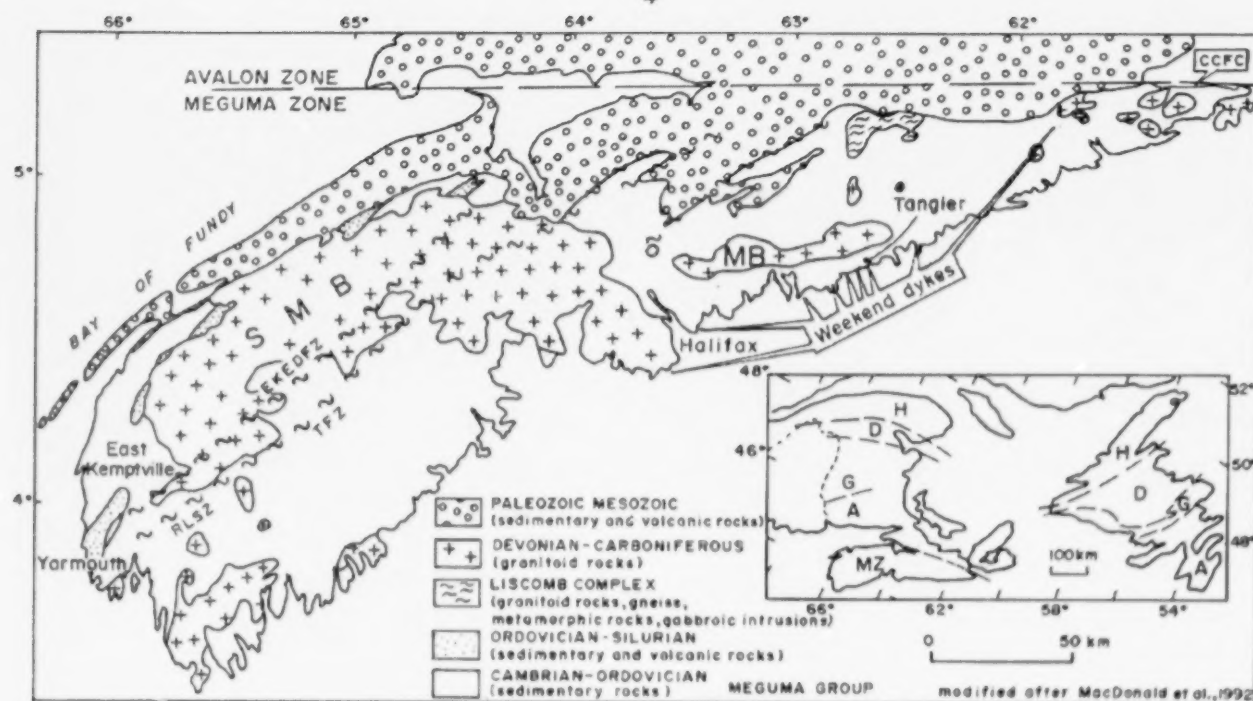


**Figure 1.2** Geological map of the Meguma Terrane showing the location of the South Mountain Batholith (SMB) and the Musquodoboit Batholith (MB). The boundary between the Meguma and Avalon Terranes is marked by the Cobequid Chedabucto fault system (CCFS). The location of the "Weekend dykes" of Ruffman and Greenough (1990), including the Tangier dyke of Chatterjee and Giles (1988), and the Liscomb Complex (Giles and Chatterjee, 1986, 1987; Clarke et al., 1993), are given. The locations of the Tobeatic fault zone (TFZ; Giles, 1985), East Kempville-East Dalhousie fault zone (EKEDFZ; Horne et al., 1988) and Rushmere Lake shear zone (RLSZ; Smith, 1985) are given.

reported  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of  $370 \pm 2$  and  $367 \pm 2$  Ma for two of the Weekend dykes in the vicinity of Tangier (Fig. 1.2) suggesting that the dykes may have been emplaced synchronously with the Liscomb gneisses. Chatterjee and Giles (1988), Eberz et al. (1988) and Eberz et al. (1991) conducted detailed petrological and geochemical studies of a suite of granulite xenoliths from one of these dykes near Tangier and concluded that these xenoliths represent upper crustal material from the Avalon terrane that was rapidly subducted beneath the Liscomb gneisses to lower crustal P-T conditions during the mid- to late-Devonian.

### 1.3 Previous Work

Several geological mapping projects have been conducted in the South Mountain Batholith and a list of previous workers with their respective subdivision criteria is presented in Table 1.1. Early mapping projects (e.g. Faribault, 1908) delineated the boundaries of the batholith, but no attempt was made to divide the granitic rocks into lithotypes. Faribault (1924) first delineated



Table 1.1 Review of criteria for subdivision of granitic rocks of the South Mountain Batholith.

| Author(s)                                    | CRITERIA |            |     |                  |      |      |      |      |              |              | COMMENTS                                                                                                                                        |
|----------------------------------------------|----------|------------|-----|------------------|------|------|------|------|--------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
|                                              | QAP      | GR<br>SIZE | TEX | MODAL MINERALOGY |      |      |      |      | PLAG<br>COMP | XEN<br>ABUND |                                                                                                                                                 |
|                                              |          |            |     | BIOT             | MUSC | CORD | GARN | MEGA |              |              |                                                                                                                                                 |
| Faribault (1924)                             |          |            |     | X                | X    |      |      |      |              |              | 2 divisions: biot granite and musc granite                                                                                                      |
| Taylor (1969)                                |          |            | X   | X                | X    |      |      |      |              | X            | 2 divisions: biot granite and musc granite with "porphyritic" (i.e. megacrystic) and "xenolith" qualifiers                                      |
| Smitheringale (1973)                         | X        | X          | X   |                  |      |      |      |      |              | X            | 7 divisions: (e.g. medium grained non-porphyritic quartz monzonite)                                                                             |
| Cormier and Smith (1973); Smith (1974, 1979) | X        |            | X   | X                | X    |      |      |      | X            |              | 4 divisions: granodiorite; porphyritic quartz monzonite; muscovite-biotite granite; and alaskite                                                |
| McKenzie (1974); McKenzie and Clarke (1975)  | X        |            | X   | X                | X    |      |      |      | X            |              | 3 divisions: granodiorite; adamellite (i.e. monzogranite); and minor intrusives (further subdivided into porphyry, alaskite and leucadamellite) |
| Charest (1976)                               | X        |            | X   | X                | X    |      |      |      | X            |              | 5 divisions: granodiorite; adamellite (i.e. monzogranite); porphyry; leucadamellite; and mica aplite                                            |
| Present study                                | X        | X          | X   | X                | X    | X    | X    | X    |              |              | 6 main divisions (descriptions in text)                                                                                                         |

Abbreviations: QAP-modal proportions of quartz-alkali feldspar-plagioclase; GR SIZE-grain size; TEX-texture; BIOT-biotite; MUSC-muscovite; CORD-cordierite; GARN-garnet; MEGA-feldspar megacrysts; PLAG COMP-An content of plagioclase; XEN ABUND-abundance of xenoliths.

different types of granite in the vicinity of Mahone Bay based on the dominance of biotite over muscovite. Taylor (1969) reported the texture (i.e. porphyritic [megacrystic in this report] or non-porphyritic), dominant mica type (i.e. biotite versus muscovite) and the presence or absence of metasedimentary xenoliths for outcrop in the western part of the batholith (west of Longitude 64°00'). However, he did not subdivide the granitic rocks into mappable units on the basis of this information. Subsequent mapping programmes employed various textural and mineralogical criteria to separate the rocks (Table 1.1).

Smitheringale (1973) mapped parts of N.T.S. map sheets 21A/12(east half), 21A/14(east half) and 21A/15(west half). He subdivided the granitic rocks of the South Mountain Batholith and the satellite plutons that intruded Cambrian to Silurian aged metasedimentary and metavolcanic rocks north of the batholith. Granitoid rocks were classified according to the relative proportions of quartz, alkali feldspars and plagioclase and subsequently designated as granodiorite and monzonite (i.e. monzogranite in this study). Rocks were further subdivided on the basis of grain size and texture (e.g. porphyritic [megacrystic in this study], equigranular, seriate). He also noted the presence of metasedimentary xenoliths, although this feature was not used as a criteria for classification. Smitheringale (1973) delineated seven granite map units using the above criteria.

McKenzie (1974) conducted reconnaissance geological mapping of the central portion of the batholith extending from Highway #8 eastward to Highway #14. Granitoid rocks were first divided on the basis of the proportions of quartz, alkali feldspar and plagioclase and termed granodiorite and adamellite (i.e. monzogranite in this study). The modal proportions of biotite and muscovite were also noted for each map unit. McKenzie (1974) observed that the granodiorite was predominantly porphyritic (i.e. megacrystic) in texture but also delineated a band of "augen"-textured granodiorite in the north-central part of his study area. Four adamellite bodies were described, including the Lake George, Springfield Lake and West Dalhousie Adamellites and the New Ross-Vaughan Complex. These bodies were further subdivided into textural and compositional sub-types (e.g. porphyritic, medium grained equigranular). In addition, numerous small bodies ( $< 1\text{-}5 \text{ km}^2$ ) of "minor intrusive", including alaskite and leucoadamellite, were outlined. These late-staged rocks were defined on the basis of the modal amounts of biotite and muscovite and the anorthite content of plagioclase feldspars.

Smith (1974) conducted reconnaissance geological mapping of the eastern portion of the batholith from the city of Halifax to St. Margaret's Bay. He divided the granitoid rocks, on the basis of the proportions of quartz, alkali feldspar and plagioclase, into granodiorite, monzonite (i.e. monzogranite in this study), muscovite-biotite granite (i.e. monzogranite/syenogranite in this study). The texture and modal amounts of biotite and muscovite were also noted for each rock type. Smith (1974) also outlined a series of late-staged alaskite bodies that intruded the above rocks. Alaskite was defined on the basis of low biotite content and anorthite content of plagioclase (i.e.  $\text{An}_{<5}$ ).

Charest (1976) applied the same rock classification scheme as McKenzie (1974) for a detailed mapping project in the New Ross area of the batholith. He divided the granitoid rocks into granodiorite, porphyritic adamellite, porphyry and leucoadamellite (i.e. megacrystic monzogranite, porphyritic leucomonzogranite and leucogranite in this study). Charest (1976) also introduced the term "mica aplite" for adamellite with fine grained equigranular matrix and coarse grained muscovite  $\pm$  biotite rosettes.

Dwyer (1976) mapped the part of the batholith between the study areas of McKenzie (1974) and Smith (1974). He divided the granitic rocks into adamellite (i.e. monzogranite) and granodiorite and noted that the monzogranitic rocks of the New Ross-Vaughan Complex

(McKenzie, 1974) extended to the east, and were continuous with the monzonite (i.e. monzogranite) rocks of the Halifax Pluton (Smith, 1974). Similarly Dwyer (1976) concluded that the granodiorite body from the New Ross-Vaughan Complex could be extended to a thin wedge of granodiorite along the margin of the Halifax Pluton.

Keppie (1979) compiled the results of McKenzie (1974), Smith (1974) and Dwyer (1976) and produced a general geology map for the batholith (Figure 1.3) consisting of a three-fold classification scheme that included granodiorite, monzogranite and alaskite.

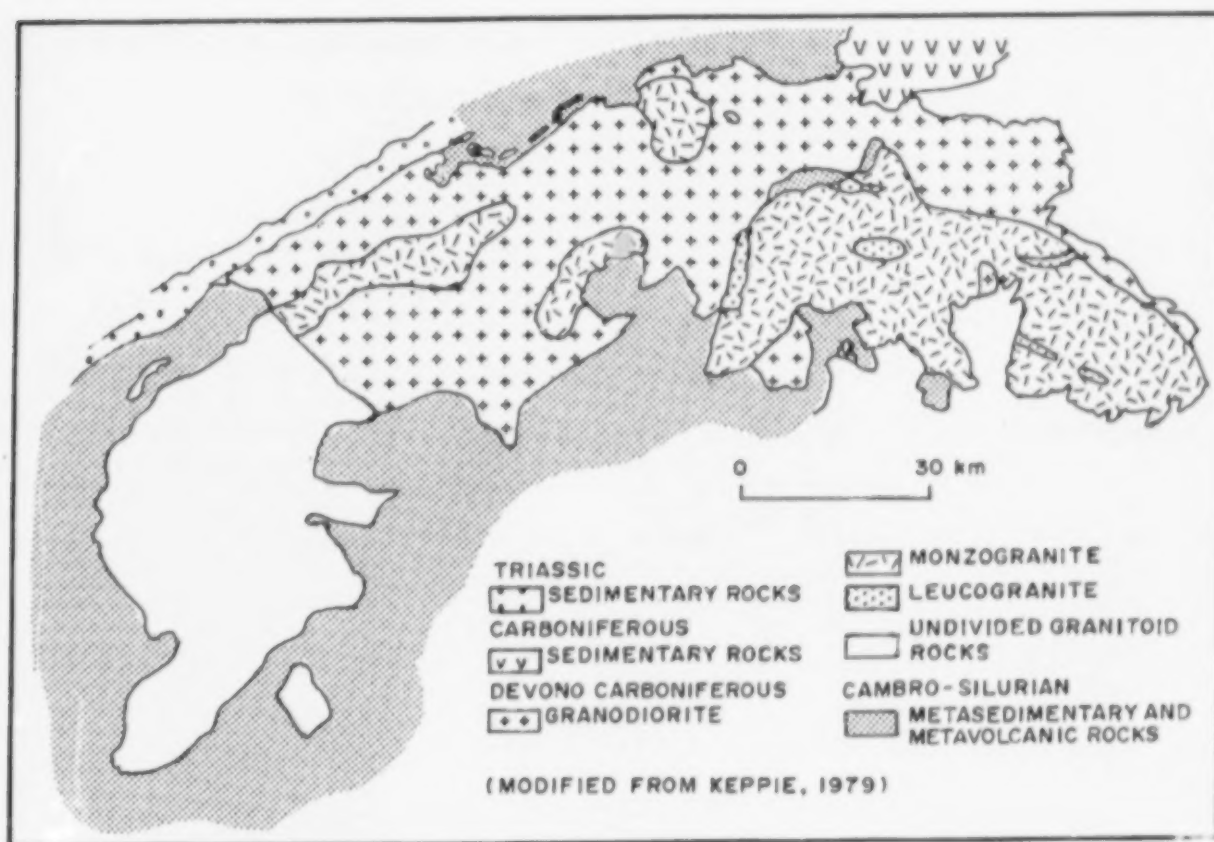


Figure 1.3 General geological map of the South Mountain Batholith, surrounding Cambro-Silurian country rocks and overlying Carboniferous and Triassic sedimentary rocks (modified after Keppie, 1979). This map was compiled from the results of McKenzie (1974), Smith (1974) and Dwyer (1976).



## Chapter 2

### METHODOLOGY AND ROCK CLASSIFICATION

#### 2.1 Mapping Methodology

Geological mapping was conducted during the 1985, 1986 and 1988 field seasons (MacDonald et al., 1985; 1987; 1988). Mapping commenced along all-weather and logging roads and easily accessible lakes and streams. Foot traverses were then used to supplement outcrop coverage in areas with poor access, diverse rock types or complex geology and helicopter traverses were also used in remote regions. Several regions are uniformly blanketed by regional ground moraine and consequently have a very low outcrop density. Geological boundaries in these regions were partly or entirely delineated using till clast distribution in the ground moraine (Graves and Finck, 1988) and/or the results of airborne gamma-ray spectrometric surveys, in particular equivalent U/equivalent Th (O'Reilly et al., 1988).

Geological information recorded in the field included: (1) grain size, texture, colour and modal mineralogy of the major rock type(s); (2) orientation, size, spacing and type(s) of dykes, veins, joints, shear zones and faults; (3) orientation and degree of development of primary fabrics or mineral alignment(s); (4) presence and style of mineralization and hydrothermal alteration; and (5) abundance and type of xenoliths (both metasedimentary and igneous). Large hand samples (approximately 2-10 kg) were routinely collected at approximately 1-2 km intervals along traverses in homogeneous rock units and more closely in heterogeneous rock units or when more than one rock type was encountered. Approximately 2500 samples were collected, all samples were slabbed and most were stained for alkali feldspar using sodium cobaltinitrate solution. Approximately 1500 of these 2500 samples, were subsequently point counted (400-1000 points/sample) using a binocular microscope and/or petrographic microscope. The entire sample collection has been archived in Nova Scotia Department of Natural Resources storage facilities in Stellarton, Nova Scotia.

Data were recorded in the field on 1:10,000 scale colour air photos and compiled in the field onto 1:15,840 (1"=1/4 mile) scale Nova Scotia Department of Lands and Forest base maps. This information was subsequently compiled on 1:50,000 scale National Topographic

Series planimetric base maps for publication. A total of fourteen bedrock geology maps have been released as Nova Scotia Department of Mines and Energy published and/or open file maps. The locations of these map sheets along with the respective authors are given in Figure 2.1. Full citations for each map are given in the References at the back of this report.

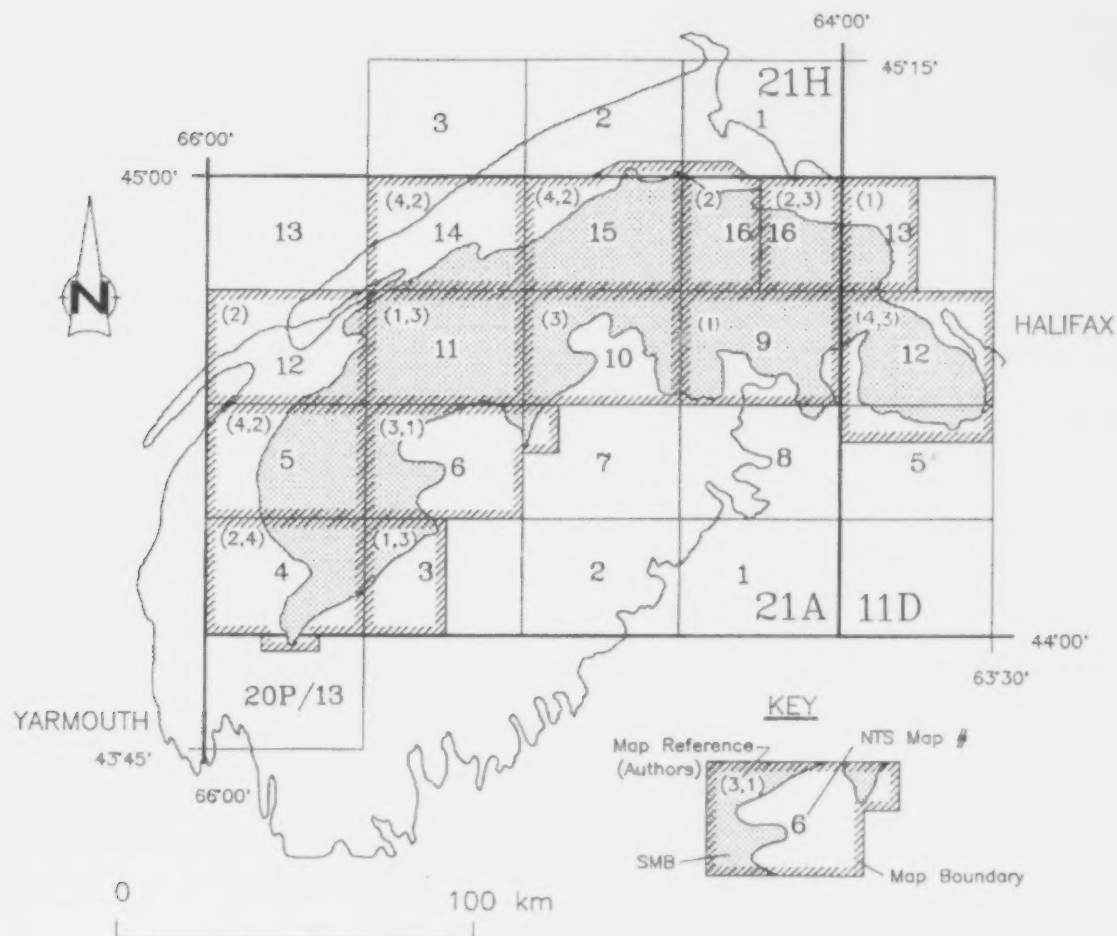


**Figure 2.1** Reference map for the fourteen 1:50,000 scale geological maps produced during the 1984-1989 South Mountain Batholith mapping project. The location of the batholith is outlined with a stipple pattern. Map boundaries for each of the National Topographic series maps are indicated with hatch marks. Additional information includes the respective author(s) and the year the map was published. Full citations are given in the references. Note that authors were ordered alphabetically and coded with numbers, including: (1) M.C. Corey; (2) L.J. Ham; (3) R.J. Horne; (4) M.A. MacDonald.

## 2.2 Rock Classification Scheme

One of the first tasks for this project was to establish a rock classification scheme. The most important aspect of this scheme is the suitability for field use. Previous mapping in the batholith utilized a myriad of rock names. For example the rocks termed monzogranite on the provincial geological map (Keppie, 1979) were previously referred to as: biotite granite and muscovite granite (Taylor, 1969); porphyritic quartz monzonite (Smitheringale, 1973); muscovite-biotite granite (Smith, 1974); and adamellite (McKenzie, 1974). Clearly there was a need for a standard system for classifying granitic rocks.

Previous classification schemes for the batholith (Table 1.1) were mostly based on the relative proportions of quartz, alkali feldspar and quartz whereas some also considered texture and grain size (e.g. Smitheringale, 1973) and/or the relative proportions of muscovite and biotite (e.g. McKenzie, 1974; Smith 1974). Some schemes also employed the anorthite content of plagioclase feldspar as a criteria for rock classification.

This study used the classification scheme of Streckeisen (1976; Figure 2.2) which is the most universally used scheme for igneous rocks. This method is based upon the modal proportions of quartz, alkali feldspar and plagioclase and is particularly useful in igneous terranes with widely ranging compositions. For example, in the Sierra Nevada Batholith of California where compositions range from gabbro to leucogranite (Bateman, 1988), or in the Coastal Batholith of Peru where rock types range from gabbro to monzogranite (Cobbing et al., 1981). Previous studies of the batholith (Smith, 1974; McKenzie and Clarke, 1975) noted a comparatively restricted range from granodiorite to monzogranite. Strict adherence to the classification scheme of Streckeisen (1976) would yield only two rock types in most of the batholith. Therefore, a modified Streckeisen (1976) classification scheme was developed based upon the results of preliminary and past mapping projects (MacDonald, 1985; Table 1.1). Granitic rocks are divided on the basis of: (1) the modal proportions of quartz, alkali feldspar and plagioclase; (2) grain size (fine <0.1 cm; medium 0.1-0.5 cm; coarse >0.5 cm); (3) texture; and (4) the modal proportion of muscovite and the combined mafic minerals (biotite, cordierite, garnet; Table 1.1).

Several terms have been adopted and/or modified from Streckeisen (1976) previous mapping projects in the batholith for use in this project. These include the compositional terms:

leucomonzogranite - mostly monzogranite, and subordinate syenogranite, containing 2-6% combined mafic minerals; and leucogranite - monzogranite, syenogranite or alkali feldspar granite with <2% combined mafic minerals. The use of the prefix 'leuco' for igneous rocks with <6% combined mafic minerals is consistent with Streckeisen (1976); and the textural terms megacryst (adj. megacrystic) - a non-genetic term for a large (generally 2.5-7 cm) crystal (mostly alkali feldspar and lesser plagioclase) in a medium- to coarse-grained rock; and porphyry (adj. porphyritic) - a granitic rock with predominantly fine-grained groundmass and medium- to coarse-grained phenocrysts.

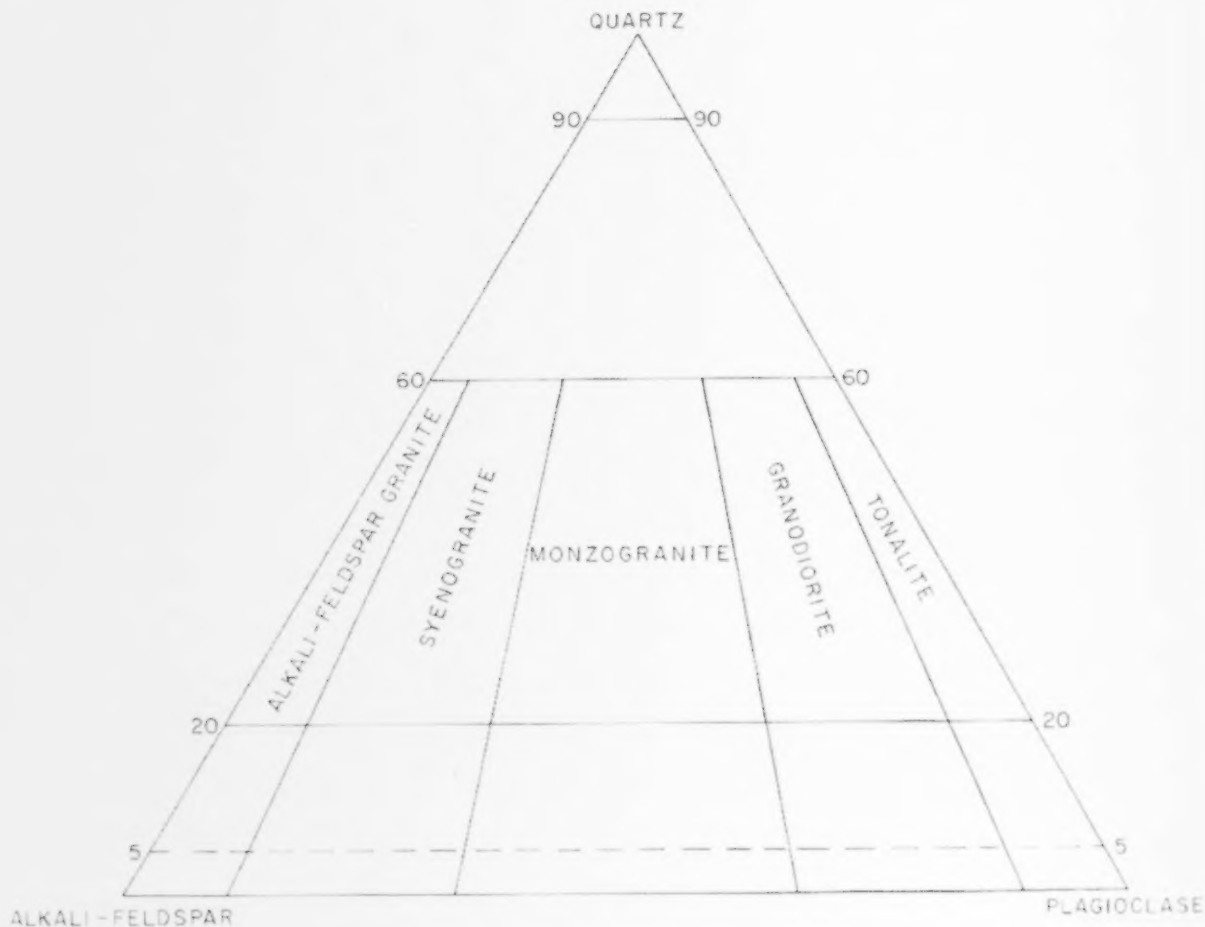


**Figure 2.2** Ternary quartz-alkali feldspar-plagioclase (i.e. QAP) classification diagram (after Streckeisen, 1976) for granitoid rocks showing the location of tonalite, granodiorite, monzogranite, syenogranite and alkali feldspar granite fields.

Streckeisen (1976) suggested that plagioclase with  $An_{\leq 5}$  should be grouped with alkali feldspar. Some previous workers in the batholith used the term alaskite for leucocratic rocks with albitic

feldspar. Some previous workers in the batholith used the term alaskite for leucocratic rocks with albitic plagioclase (McKenzie, 1974; Smith 1874). It should be stressed, however, that albitic plagioclase with  $An_{\leq 5}$  is present in many rocks and may vary from minor modal amounts in some leucomonzogranites to the only plagioclase feldspar in some leucogranite bodies (MacDonald et al., 1992). Determination of the exact modal amounts in the various rock units in the batholith would require vast amounts of microprobe data. Clearly this would be beyond the scope of a useful "field" classification scheme. Therefore for the purpose of this project all plagioclase compositions are grouped together.

The batholith was divided into six main rock types using the above classification scheme. These include biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse-grained leucomonzogranite, fine-grained leucomonzogranite and leucogranite. In addition to the six main rock types, several small bodies ( $< 100 \text{ m}^2$ - $1 \text{ km}^2$ ) of fine-grained, often porphyritic, granodiorite and monzogranite with a high percentage of biotite and common metasedimentary xenoliths, termed mafic porphyry, have been delineated.

### 2.3 Organization of Rock Units

The batholith comprises more than two hundred separate mappable granitic bodies that must be organized before larger problems, such as emplacement history or petrogenesis, can be dealt with effectively. In general, the grouping of granitic rocks requires vast quantities of petrological and geochemical data. However, since the data available for this report are quite limited, the current organization of granitic bodies must be considered somewhat provisional and are hence subject to future modification.

Geological mapping projects in other worldwide granitic terranes have employed various schemes for organizing rock units. Pitcher and Berger (1972) assigned the various granitic rock types in the Donegal region of Ireland into eight plutons based upon field relations, including mode of emplacement, and compositional variations within these rock units. Cobbing et al. (1981) established a scheme for classification of granitic rocks of the western Cordillera of northern Peru. The basic mappable granitic body in their scheme was "pulse". These were subsequently grouped into "units" which in turn were amalgamated into "plutons". Major magmatic episodes, based mostly upon geochronological data, which were represented by



numerous plutons, were termed "super units". Bateman (1988) established a hierarchical scheme that, in increasing order, included "pluton", "lithodeme", "intrusive suite" and "super suite". Prior to the present study, most mapping projects in the South Mountain Batholith simply used rock types with no classification scheme (e.g. Taylor, 1969; Smitheringale, 1973). However, McKenzie (1974), McKenzie and Clarke (1975), and later Smith and Turek (1976) and Smith (1979) established adamellite (re monzogranite) plutons that were considered to intrude an envelope of biotite granodiorite. These plutons contained several textural variations such as megacrystic and porphyritic monzogranite (McKenzie, 1974). An essential consideration, when the organizational scheme for the batholith was established, was at least a partial retention of the term pluton and, where possible, the preservation of previously published pluton names (e.g. Davis Lake, New Ross and Halifax Plutons). The chief motive for this was the minimizing of unnecessary confusion that an entirely new scheme would create. The following section outlines the system for organization of granitic rocks of the South Mountain Batholith.

### 2.3.1 Map Body

A single body of intrusive rock that is continuous is termed a map body. The map body of this study is equivalent to the "pulse" of Cobbing et al. (1981), "pluton" of Bateman (1988) and "member" among stratified sedimentary rocks (Table 2.1). Contacts with surrounding igneous rocks are either intrusive or gradational whereas contacts with metasedimentary and metavolcanic country rocks are ubiquitously sharp and intrusive, with the exception of some mafic porphyry bodies (see discussion below). The relative ages of adjacent map bodies are generally difficult to establish due to poor outcrop exposure in much of the batholith and thus a lack of exposed contacts. However, in some locations it was possible to determine sequences of intrusion based on cross-cutting relationships of dykes, presence of inclusions of older map bodies in younger, or by truncated fabrics, aplite dykes or metasedimentary xenoliths in older map bodies. There is a paucity of chilled contacts, as manifest by reduction of grain size or textural changes, between adjacent granitic map bodies. The author favours an explanation whereby most map bodies were emplaced during a narrow time interval, thus later map bodies were emplaced before early bodies were cooled significantly. The entire batholith then cooled as a coalesced mass. This proposition is supported by geochronological evidence as discussed in Chapter 8.



Table 2.1. Summary of the organization of rocks in the South Mountain Batholith. Organizational schemes from the western cordillera of northern Peru (Cobbing et al., 1981), the Sierra Nevada Batholith of California (Bateman, 1988) and stratified sedimentary rocks are also included.

| SMB      | # Present | Cobbing et al. (1981) | Bateman (1988)  | stratified<br>sedimentary rocks |
|----------|-----------|-----------------------|-----------------|---------------------------------|
| Map Body | 260       | pulse                 | pluton          | member                          |
| Map Unit | 49        | unit                  | lithodeme       | formation                       |
| Pluton   | 13        | pluton                | intrusive suite | group                           |
| Stage    | 2         | super unit            | super suite     | super group                     |

Most map bodies are not continuous *sensu stricto* because of the presence of glacial moraine which blankets much of the batholith. Map bodies are therefore inferred to be continuous based upon available outcrop and glacial till clast information (Finck et al., 1989). Geological mapping during this project has delineated 260 individual map bodies, ranging in size from  $< 1$  to  $> 1,000$  km<sup>2</sup>, within the contiguous South Mountain Batholith. Some map bodies are characterized by homogeneous texture and grain size, such as the Cloud Lake monzogranite (MacDonald and Ham, 1992), whereas others display diverse textural variations, such as the Tantallon leucomonzogranite (MacDonald and Horne, 1987). Similarly, some map bodies are mineralogically and geochemically homogeneous whereas others are compositionally zoned from one side or end to the other, such as the Davis Lake leucomonzogranite (MacDonald et al., 1992).

### 2.3.2 Map Unit

The term "map unit" in this study is defined as a mappable unit of granitic rock and is a term that is equivalent to "formation" among stratified sedimentary rocks and corresponds to the "unit" of Cobbing et al. (1981), and the "lithodemes" of Bateman (1988; Table 2.1). Map units consist of a place name or prominent geographical feature, followed by a rock type that denoted the average modal composition of the rock, for example the Tantallon leucomonzogranite (MacDonald and Horne, 1987) or the Salmontail granodiorite (Ham and Horne, 1987). Note that the full rock

type is generally not given, for example the Sandy Lake monzogranite is actually a biotite monzogranite whereas the Harrietsfield monzogranite is actually a muscovite-biotite monzogranite. This convention was adopted for sake of brevity. Two or more intrusive bodies composed of similar texture, grain size, modal mineralogy and composition (i.e. modal quartz-alkali feldspar-plagioclase) with similar field relations with surrounding igneous rocks in approximately the same geographical region are assumed to belong to the same map unit. It is assumed that map bodies of the same map unit crystallized from a common magma and may in fact have been connected at depth at the time of their intrusion. A few map units consist of a single map body (generally  $> 100 \text{ km}^2$ ), for example the Whale Lake monzogranite (Horne, 1987). The assignment of map bodies to map units is entirely based upon field criteria and subsequently may be subject to future modification as additional geochemical, isotopic and geochronological data become available.

Forty-nine (49) map units were identified in the batholith. The distribution of these map units is given in Figure 2.3 (in pocket at back of report). A full description of the textural/mineralogical aspects and field relations of the 49 map units are given in the fourteen 1:50,000 scale geological maps with marginal notes as outlined in Figure 2.1.

### 2.3.3 Pluton

The term pluton in this study is defined as a group of related granitic rocks and is equivalent to "group" among stratified sedimentary rocks. Pluton of this study corresponds to the "pluton" of Cobbing et al. (1981) and "intrusive suite" of Bateman (1988; Table 2.1). Map units were assigned to plutons on the basis of the following criteria: 1) map units must be located in the same general region of the batholith and, in general, are contiguous; 2) map units may share unique or characteristic textural, mineralogical or geochemical features; 3) megacrystic units of individual plutons may display normal and/or reverse compositional zoning which is manifest by mineralogy and/or major, trace and isotopic geochemistry; 4) map units may be arranged concentrically, particularly in some zoned plutons such as the Halifax Pluton (MacDonald and Horne, 1987); 5) map units of younger plutons may be in intrusive or fault contact with those of older plutons; 6) younger plutons may truncate compositional zoning patterns of older plutons. The assignment of map units to plutons is dependant on an extensive petrographic and geochemical database. At present, the database is limited to specific regions of the batholith. Consequently, the number and

specific boundaries of the plutons are tentative and may be revised as additional data become available.

Thirteen plutons were outlined in the batholith. A description of the geological features of plutons is given in Chapter 3. A map showing their locations is given in Figure 2.3 (in pocket at back). The thin lines within individual plutons in Figure 2.3 are generalized compositional isopleths (no units of measure) determined from point counting and whole rock geochemistry. The arrows that are oriented perpendicular to the isopleths indicate increasing differentiation index. The plutons can be divided into early Stage I, comprising mostly granodiorite and monzogranite, and late Stage II, comprising monzogranite, leucomonzogranite and leucogranite. The two stages are equivalent to the "super-units" of Cobbing et al. (1981), "super suites" of Bateman (1988) and "super group" among stratified sedimentary rocks.

## Chapter 3

## FIELD RELATIONS

## 3.1 Major Rock Types

The following section outlines the important geological features and of the major rock types of the batholith, including biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse grained leucomonzogranite, fine grained leucomonzogranite and muscovite leucogranite. There are mineralogical and textural differences between individual map units and, consequently, this section presents the overall characteristics of rock types that are common to all units. A summary of textural and mineralogical features of these rocks is given in Table 3.1.

Table 3.1. Summary of overall textural and petrographic characteristics of the main rock types in the South Mountain Batholith.

| ROCK TYPE                        | % of SMR | GRAIN SIZE | DOMINANT TEXTURES | BIOTITE % | MUSCOVITE % | MUSCOVITE Type | PLAGIOCLASE An | PLAGIOCLASE Zoning | K-SPAR EXSOL                | CORD % | AND % | TOPAZ % | XENOLITHS       |
|----------------------------------|----------|------------|-------------------|-----------|-------------|----------------|----------------|--------------------|-----------------------------|--------|-------|---------|-----------------|
| Leucogranite                     | 0.7%     | f-m(c)     | porp, equ, pegm   | 0-2       | 3-28        | euh > repl     | <5             | unzoned            | non-evolved                 | tr.    | 0-2   | 0-8     | none            |
| Fine-grained leucomonzogranite   | 6.8%     | f-m(c)     | porp, equ         | 2-7       | 3-13        | ↑              | ↑              | ↑                  | ↑                           | tr.    | 0-tr  | 0       | rare            |
| Coarse-grained leucomonzogranite | 21.8%    | m-c(f)     | mega, seri        | 2-7       | 4-8         | repl > euh     | ↑              | zoned > unamed     | patch > rod & bead perthite | tr-5   | 0-tr  | 0       | rare            |
| Muscovite-biotite monzogranite   | 8.9%     | m-c(f)     | mega, seri, equ   | 7-12      | 1-3         | ↑              | ↑              | ↑                  | ↑                           | tr-5   | 0     | 0       | common          |
| Biotite Monzogranite             | 52.2%    | m-c(f)     | mega, seri        | 10-17     | tr-1        | ↑              | ↑              | ↑                  | ↑                           | tr-1   | 0     | 0       | common-abundant |
| Biotite granodiorite             | 9.6%     | m-c(f)     | mega, seri        | 15- > 25  | tr          | repl           | <5-35          | zoned              | rod & bead perthite         | tr.    | 0     | 0       | abundant        |

EXPLANATION: GRAIN SIZE - f = fine (<0.1 cm), m = medium (0.1-0.5 cm), c = coarse (>0.5 cm) brackets denote minor occurrence  
 DOMINANT TEXTURE: equ = equigranular, porp = porphyritic, pegm = pegmatitic, mega = megacrystic, seri = seriate, listed in descending order of importance  
 BIOTITE, MUSCOVITE, CORD (CORDIERITE), AND (ANDALUSITE), TOPAZ % - modal determinations from point counting (500-1000 points) of stained rock slabs and thin sections  
 MUSCOVITE TYPE: euh = euhedral (primary?), repl = replacement (secondary)  
 PLAGIOCLASE An = anorthite content (from microprobe analysis)  
 K-SPAR EXSOL = alkali feldspar exsolution textures  
 XENOLITHS = abundance of metasedimentary xenoliths: abundant = several in all outcrop; common = a few in most outcrop; rare = minor occurrence in some outcrop.

The distribution of rock types for the entire batholith is given in the 1:250,000 scale compilation map (Figure 2.3, in pocket at back). Each rock type description includes the modal amounts of biotite, cordierite, garnet and andalusite, which were obtained from point counting of rock slabs (up to 1500 points depending upon size of slab) and visual modal estimates of hand specimens. The modal amounts of muscovite are mostly based upon point counting of thin sections, which yielded significantly higher values than for rock slabs that were obtained using

a binocular microscope. Modal amounts of topaz, which only occurs in leucogranite, were determined by point counting thin sections. Complete petrographic and mineralogical descriptions of each rock type are given in Chapter 4. In the following section the term xenolith refers to inclusions with sedimentary, metamorphic (e.g. porphyroblastic) or granitoid textures that strongly contrast the texture and modal mineralogy of the host unit. Xenoliths have a wide variety of textures and grain sizes and have previously been interpreted as metasedimentary in origin (Jamieson, 1974; Clarke and Halliday, 1980) and as both metasedimentary and granitoid in origin (MacDonald et al., 1992). A more complete description of xenoliths is given below.

### 3.1.1 Biotite Granodiorite

Biotite granodiorite units are mostly light grey in colour, except for localized alteration zones, which mostly consist of pink to red coloured hematized zones. Rocks are predominantly medium- to coarse-grained and mostly have megacrystic texture, with alkali feldspar, and to a lesser extent plagioclase, megacrysts (Plate 3.1 a). Some granodiorite units have medium- to coarse-grained seriate texture (Plate 3.1b). Several units have medium-grained seriate to equigranular (Plate 3.1e) textures, such as the units that occur along the margins of the Halifax Pluton on map sheet 11D/12 (MacDonald and Horne, 1987), along Highway #101 in Mount Uniacke (Corey, 1987) and the Five Island Pluton on map sheet 21A/16 (Ham and Horne, 1987). These units are denoted by a pattern in Figure 2.3 (in pocket at back). Biotite granodiorite typically contains 15-25% biotite (with accessory apatite, zircon, monazite, xenotime, ilmenite) and trace amounts of muscovite, cordierite and garnet.

Biotite granodiorite units comprise approximately 9.6% of the batholith. Most granodiorite occurs in Stage I plutons, however, some units were noted along the margins of the Stage II Halifax and Davis Lake plutons (MacDonald and Horne (1987) and Ham and MacDonald (1994) respectively). The "type section" for megacrystic granodiorite is along Highway #101 from approximately 0.5 km east of the Lequille intersection, eastward to the Spurr Road overpass (Corey and Horne, 1994b). The "type section" for non-megacrystic to seriate textured granodiorite is along Dunbrack Street, in Halifax, between the St. Margaret's Bay Road and Old Sambro Road (MacDonald and Horne, 1987). Biotite granodiorite is the predominant rock type in the Five Island Lake Stage I pluton. In contrast, it is a subordinate rock type in the Salmontail Lake, Scrag Lake and Cloud Lake Stage I plutons. In these plutons granodiorite mostly occurs



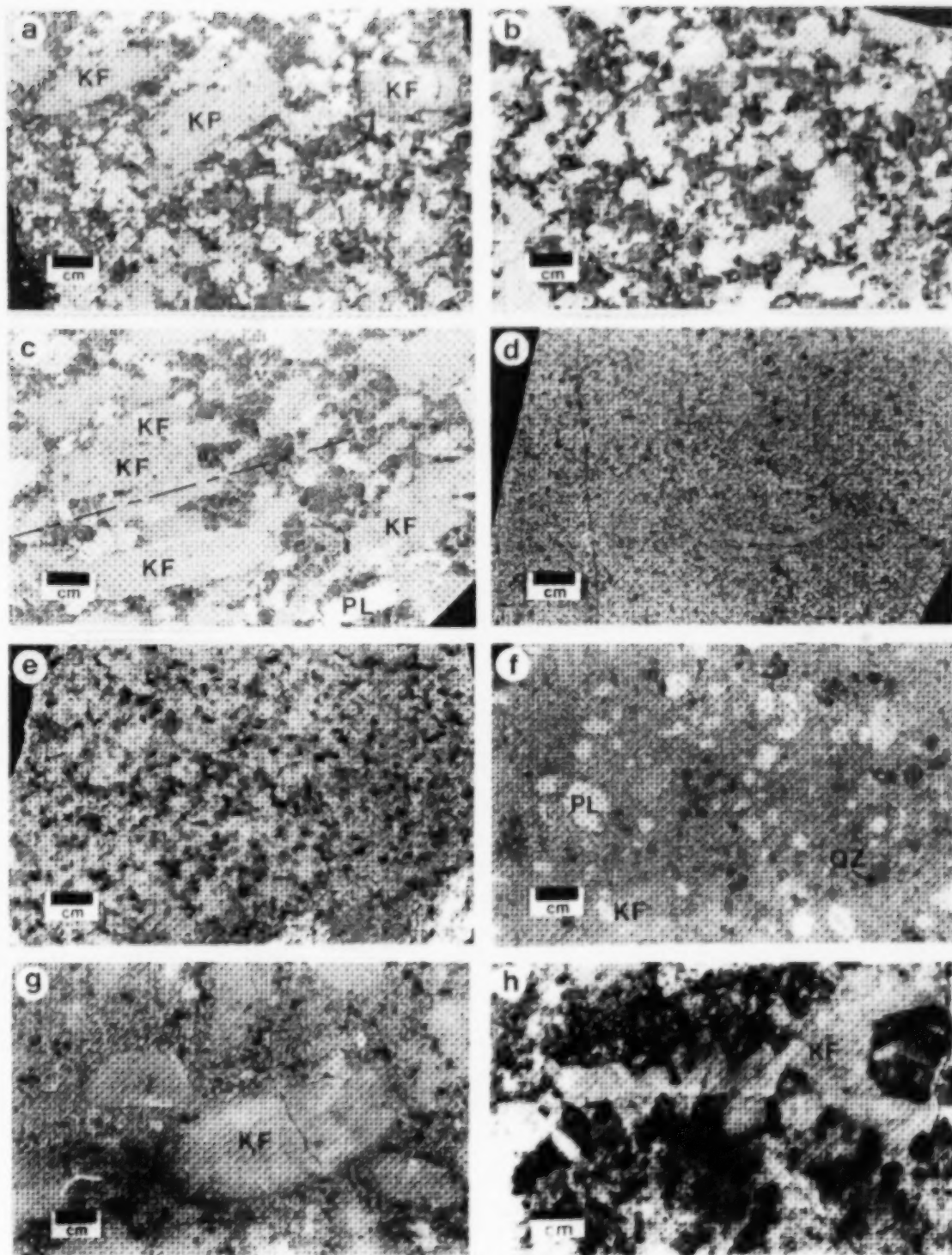


Plate 3.1 Characteristic textural variations for the granitoid rocks of the South Mountain Batholith. (a) medium- to coarse-grained megacrystic; (b) medium- to coarse-grained seriate; (c) medium- to coarse-grained megacrystic with parallel alignment of feldspar megacrysts; (d,e) fine- and medium-grained equigranular; (f,g) fine- to medium-grained and fine- to coarse-grained porphyritic; (h) coarse-grained pegmatitic. Abbreviations include: KF-alkali feldspar; PL-plagioclase; QZ-quartz.



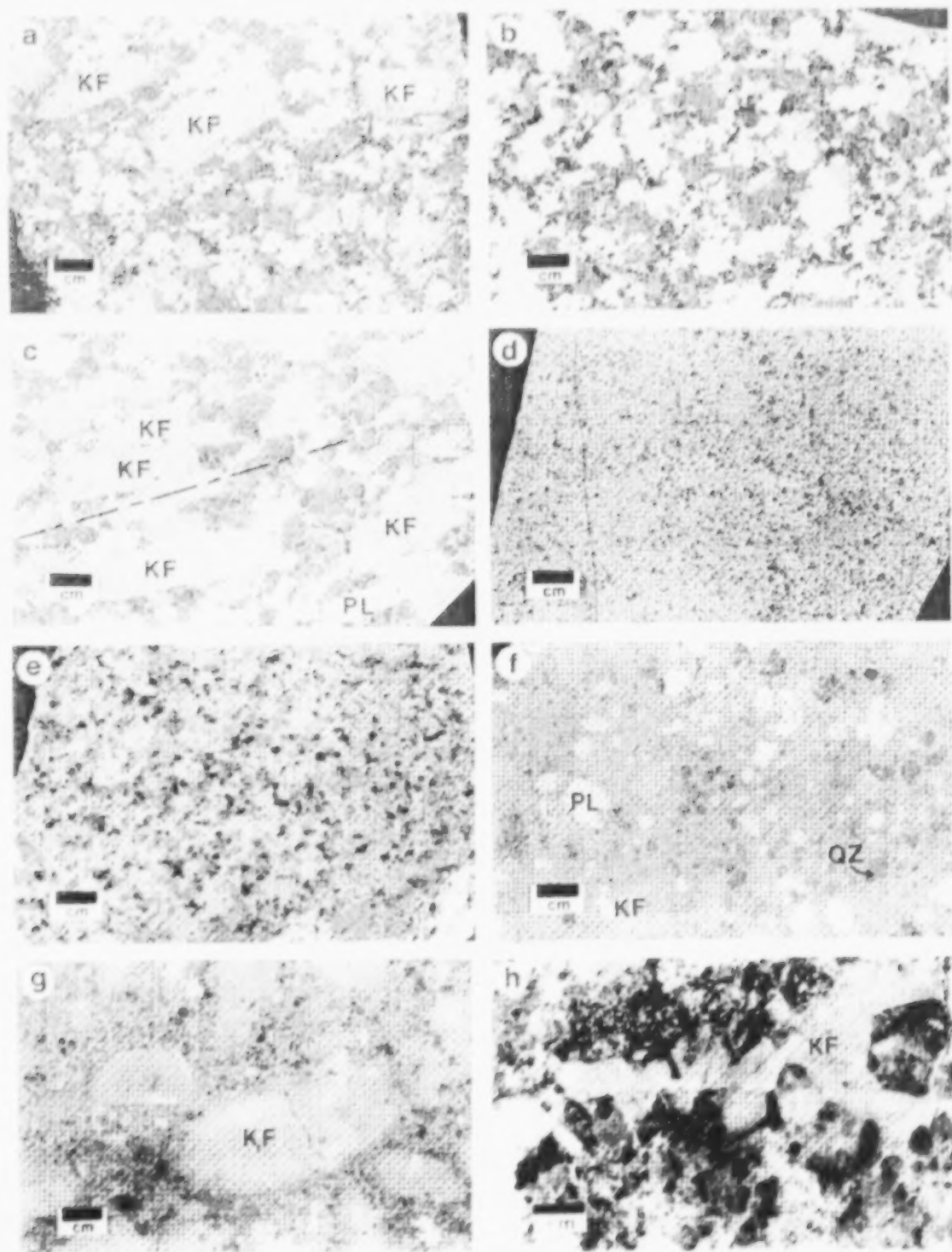


Plate 3 | Characteristic textural variations for the granitoid rocks of the South Mountain Batholith. (a) medium- to coarse-grained megacrysts in medium- to coarse-grained matrix. (b) medium- to coarse-grained megacrysts with parallel alignment of feldspar megacrysts. (c) fine- to medium-grained and medium-grained megacrysts. (d) fine- to medium-grained and fine- to coarse-grained megacrysts. (e) fine- to medium-grained and fine- to coarse-grained megacrysts. (f) fine- to medium-grained and fine- to coarse-grained megacrysts. (g) fine- to medium-grained and fine- to coarse-grained megacrysts. (h) fine- to medium-grained and fine- to coarse-grained megacrysts. Abbreviations: KF = quartz, PL = plagioclase, QZ = quartz.

particularly in normally zoned parts of the Scrag Lake and Salmontail Lake plutons. Contacts with metasedimentary and metavolcanic country rocks, where observed, are mostly sharp and intrusive (Plate 3.2). The most notable exception is in the Boot Lake granodiorite (MacDonald and Ham, 1992) where "wispy" zones of mafic porphyry (see below) are developed along the contacts with the Meguma Group metasediments (Plate 3.3). Contacts with biotite monzogranite units in most Stage I plutons and the Stage II Halifax Pluton are gradational. In fact, most of the contacts in Figure 2.3 (in pocket at back) are defined on the basis of point counting of rock slabs and are difficult to detect in the field. In contrast, contacts with the muscovite bearing rocks of both the Stage I and II plutons are ubiquitously sharp and intrusive. Biotite granodiorite units have the highest proportion of xenoliths (Plate 3.4), with the exception of the volumetrically minor mafic porphyry (see below). In general, the highest percentages of xenoliths were noted in areas of granodiorite with the highest percentages of biotite, and locally in close proximity to country rock contacts as along Highway #101 near Mount Uniacke (Jamieson, 1974; Corey, 1987).



**Plate 3.2** Sharp intrusive contact between granitoid rocks of the South Mountain Batholith and metasedimentary rocks of the Meguma Group. Note the injection of granitoid rocks along bedding planes and the presence of angular xenoliths of Meguma Group rocks. Width of photograph is approximately 2 metres.

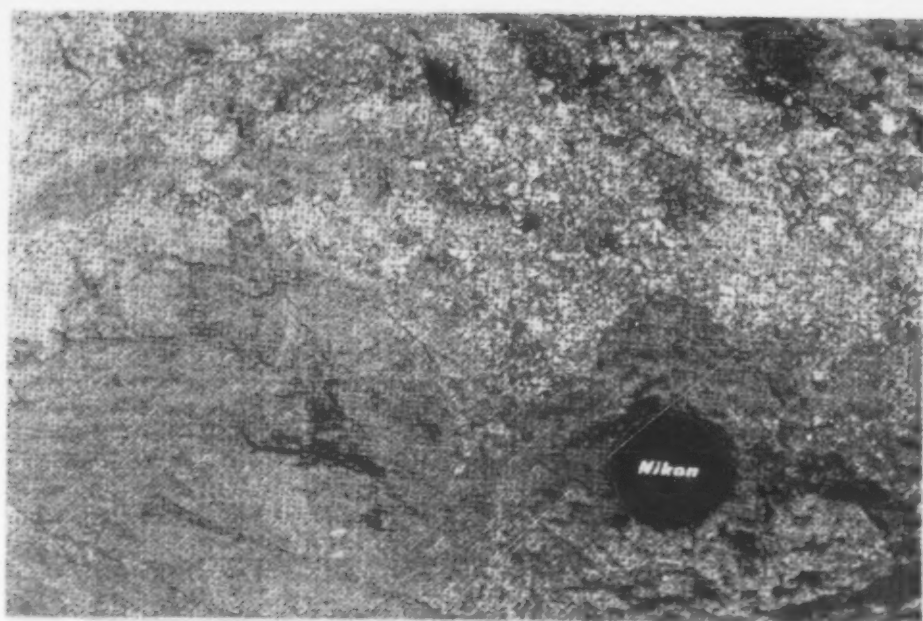


Plate 3.3 "Wispy" bands of biotite-rich mafic porphyry developed along the contact between the Boot Lake granodiorite and metasedimentary rocks of the Meguma Group (MacDonald and Ham, 1992). Note the diffuse nature of the contacts which strongly contrasts the sharp intrusive contacts shown in Plate 3.2.

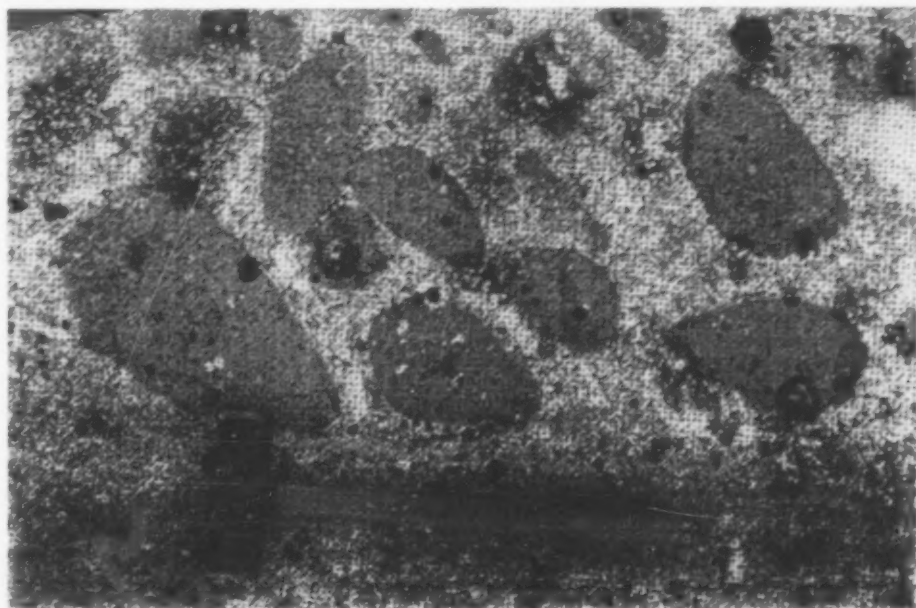


Plate 3.4 Concentration of rounded metasedimentary xenoliths in biotite granodiorite along the northern margin of the Halifax Pluton (MacDonald and Horne, 1987). Note the presence of light grey feldspar porphyroblasts in most xenoliths, and the presence of highly assimilated(?) xenoliths with granitoid textures. Hammer handle is 40 cm long.

### 3.1.2 Biotite Monzogranite

Biotite monzogranite units are mostly light grey in colour, except for restricted hematized zones that have reddish colouration. Rocks are predominantly medium- to coarse-grained and have megacrystic texture, with alkali feldspar, and to a lesser extent plagioclase, megacrysts. In fact, these rocks strongly resemble biotite granodiorite units. Some monzogranite units display a medium- to coarse-grained seriate texture in part. Several bodies of monzogranite with fine- to coarse-grained porphyritic texture (Plate 3.1f) were noted in parts of the batholith, for example on map sheet 21A/11 (Corey and Horne, 1994b) and map sheet 21A/10 (Horne, 1993) and are denoted by a pattern in Figure 2.3 (in pocket at back). Biotite monzogranite typically contains 10-17% biotite (with accessory apatite, zircon, monazite, xenotime, ilmenite) and trace-1% muscovite and cordierite. These rocks are mostly distinguished from granodiorite on the basis of proportions of quartz-alkali feldspar-plagioclase and, to a lesser degree, lower biotite content.

Biotite monzogranite units comprise approximately 52.2% of the batholith and hence are the predominant rock type. Most biotite monzogranite is restricted to Stage I plutons, however, some units were noted along the margins of the Stage II Halifax and Davis Lake plutons (MacDonald and Horne (1987) and Ham and MacDonald (1994) respectively). Some biotite monzogranite bodies were also noted in the central parts of the New Ross Stage II pluton, although these rocks are interpreted as "roof pendants" of the adjacent Stage I Pluton. There are numerous excellent exposures of biotite monzogranite throughout the entire batholith, however, perhaps the best "type section" for megacrystic monzogranite is along Highway #103 from the Ingram River on map sheet 11D/12 (MacDonald and Horne, 1987) eastward to the intersection with Highway #14, near Chester (Corey, 1990). Note that there are also several small bodies of fine- and coarse-grained leucomonzogranite along this portion of Highway #103. The "type section" for porphyritic textured biotite monzogranite is along a series of secondary roads northeast of Highway #8, in the central part of map sheet 21A/11 (Corey and Horne, 1994b). Biotite monzogranite is the predominant rock type in all Stage I plutons with the exception of the Five Island Lake pluton which is mostly composed of biotite granodiorite. Contacts with metasedimentary and metavolcanic country rocks, where observed, are mostly sharp and intrusive. The most notable exception is in portions of the Cloud Lake monzogranite



(MacDonald and Ham, 1992) where "wispy" zones of mafic porphyry, similar to those in the Boot Lake granodiorite are developed along the contacts with the Meguma Group metasediments (see below for discussion of origin of these rocks). Contacts with biotite granodiorite units in most Stage I plutons and the Stage II Halifax Pluton are gradational. In fact, most of the contacts in Figure 2.3 (in pocket at back) are defined on the basis of point counting of rock slabs and, as noted above, are difficult to detect in the field. In contrast, contacts with the muscovite bearing rocks of both the Stage I and II plutons are ubiquitously sharp and intrusive (Plate 3.5). Biotite monzogranite units have common to abundant xenoliths, the highest percentages being in the rocks with the highest modal amounts of biotite and locally in portions of biotite monzogranite units in close proximity to the country rock contacts.



**Plate 3.5** Sharp intrusive contact between biotite monzogranite (BMG) of the Stage I Salmontail Lake Pluton and coarse grained leucomonzogranite (CGLMG) of the Stage II New Ross Pluton. Note the lack of contact-related features including the development of chilled margins in both units. Hammer handle is approximately 1 metre long.

### 3.1.3 Muscovite-Biotite Monzogranite

Muscovite-biotite monzogranite units are mostly light grey in colour, except for restricted hematized zones that have pink to red colouration. The Harrietsfield (MacDonald and Horne, 1987), Sherwood (Ham and Horne, 1987), Whale Lake (Horne, 1993), Kerr Lake (MacDonald



and Ham, 1992) and Soloman Lake (Ham and MacDonald, 1994) muscovite-biotite monzogranite units in the Halifax, New Ross, East Dalhousie and Davis Lake Stage II plutons are predominantly medium- to coarse-grained and have moderately megacrystic texture, with 3-20% alkali feldspar megacrysts. Individual megacrysts vary in size from  $<2.5$  to  $>7$  cm in length. The Kejimikujik Lake (Horne and Corey, 1994) and Button Brook (MacDonald and Ham, 1994b) units are texturally similar to the above units but are typified by trace- $\approx 10\%$  small ( $\approx 1 \times 2$ -2.5 cm) alkali feldspar megacrysts. The West Dalhousie monzogranite comprises two separate textural types (Corey and Horne, 1989b; MacDonald and Ham, 1992). The first is a very megacrystic phase with 20 to 40% uniformly sized ( $1 \times 3$  cm) alkali feldspar megacrysts (Plate 3.6). The second variety is fine- to medium-grained with moderately equigranular or slightly megacrystic texture. This phase is denoted by a pattern in Figure 2.3 (in pocket at back). Rapakivi textures, with albite rims enclosing cores of alkali feldspar (Plate 3.7), are a common feature in muscovite-biotite monzogranite units. Muscovite-biotite monzogranite units typically contain 7-12% biotite (with accessory apatite, zircon, monazite, xenotime, ilmenite), 1-3% muscovite and trace-5% cordierite. These monzogranitic rocks are distinguished from biotite monzogranite units on the basis of significant proportions of muscovite, easily recognizable in hand specimen, and lower proportions of biotite.

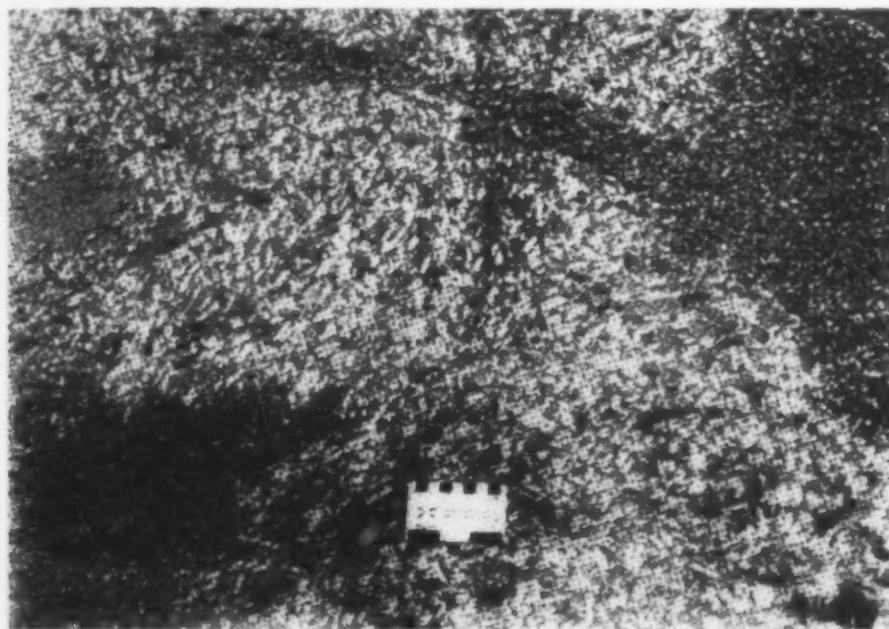


Plate 3.6 Typical outcrop of megacryst-rich West Dalhousie muscovite-biotite monzogranite with abundant (approximately 35%) uniform-sized alkali feldspar megacrysts ( $\approx 1 \times 2$ -2.5 cm).

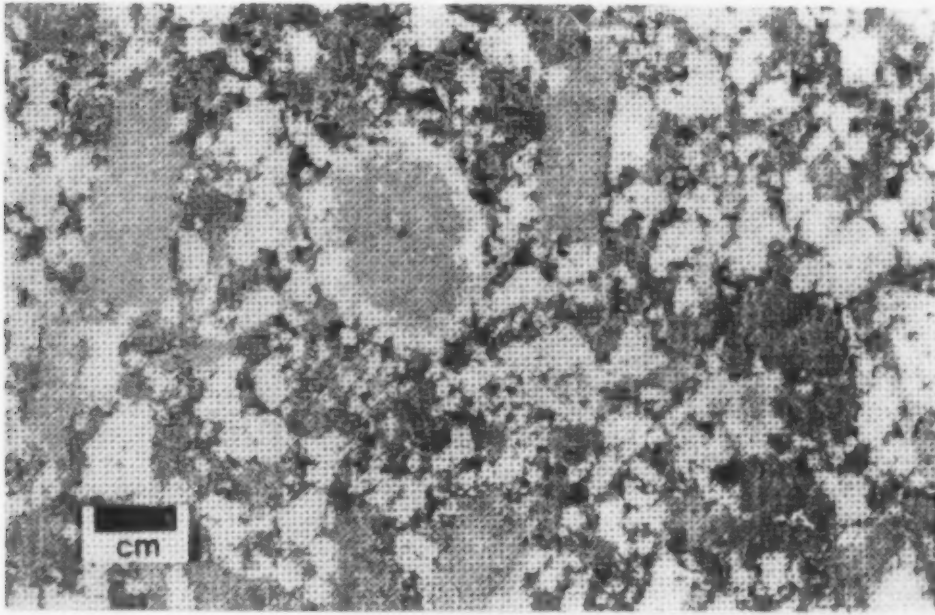


**Plate 3.7** Rapakivi texture in the Harrietsfield muscovite-biotite monzogranite with plagioclase (albite?) rim surrounding a ragged-textured alkali feldspar megacryst. The corroded grain boundary indicates that the alkali feldspar was replaced by secondary plagioclase.

Muscovite-biotite monzogranite units comprise approximately 8.9% of the batholith and are restricted to, or form the dominant rock type in, Stage II plutons. Muscovite-biotite monzogranite units occur both in the core regions of reversely zoned parts of the Halifax (MacDonald and Horne, 1988) and New Ross (Ham and Horne, 1987) plutons, and the margins of the normally zoned Morse Road pluton (MacDonald and Ham, 1994b) and normally zoned portions of the New Ross and Davis Lake (Ham and MacDonald, 1994) plutons. The best "type section" for the moderately megacrystic textural variety is along the Old Sambro Road near Harrietsfield, south of Halifax (MacDonald and Horne, 1987). The "type section" for the very megacrystic textural variety is along a series of secondary roads near Squirreltown, east of Highway #10 on map sheets 21A/14 (MacDonald and Ham, 1994b) and 21A/15 (MacDonald and Ham, 1992). The "type section" for the equigranular textural type is along the West Dalhousie Road in the north-central portion of 21A/11 (Corey and Horne, 1994b). Contacts with metasedimentary country rocks, where observed (e.g. Whale Lake monzogranite; Horne, 1993), are sharp and intrusive. Contacts between muscovite-biotite monzogranite units and other granitic rock types in the batholith are mostly intrusive, with the exception of the contact with the Harrietsfield monzogranite in the

Halifax Pluton (MacDonald and Horne, 1987) which, in part, is in gradational contact with the adjoining coarse-grained leucomonzogranite unit. Muscovite-biotite monzogranite units have common xenoliths, the highest percentages being in the rocks with the highest modal amounts of biotite.

#### 3.1.4 Coarse-Grained Leucomonzogranite

Coarse-grained leucomonzogranite units show a wide variation in colour with buff, pink and whitish-grey colours predominating. Localized areas with moderate to intense hematization have reddish colouration. Most units are medium- to coarse-grained with megacrystic texture (Plate 3.1c) although fine- to coarse-grained, slightly megacrystic to seriate textures are commonly developed in parts of most units. The Spectacle Lake leucomonzogranite unit, which is exposed in the central portions of map sheet 21A/09 (Corey, 1990), is characterized by a very megacrystic texture ( $>35\%$ ) with uniformly large (i.e.  $>5$  cm) alkali feldspar megacrysts. The Spectacle Lake unit is also denoted by a pattern in Figure 2.3. A body of predominantly equigranular textural variety coarse-grained leucomonzogranite is exposed in the northwestern part of the New Ross Pluton (Ham, 1990) and is denoted by a pattern in Figure 2.3. Rapakivi textures, with albite rims on alkali feldspar, are a common feature. Coarse-grained leucomonzogranite typically contains 2-7% biotite (with accessory apatite, zircon, monazite, xenotime, ilmenite), 4-8% muscovite, trace-5% cordierite and trace amounts of andalusite. Coarse-grained leucomonzogranite is distinguished from other coarse-grained monzogranite and granodiorite rocks on the basis of the low modal biotite and abundant muscovite, commonly as large grains ( $\leq 1$  cm) that are easily recognizable in hand specimen.

Coarse-grained leucomonzogranite units comprise approximately 21.8% of the batholith and are restricted to, and are the dominant rock type in, most Stage II plutons, with the exception of the West Dalhousie and Kejimikujik plutons. The best "type section" for this rock type is along Highway #12 from New Ross, south to Seffernsville on map sheet 21A/09 (Corey, 1990). The "type section" for the very megacrystic textural variety is along a series of secondary roads near Spectacle Lake, between Highways #12 and #14, in the west-central part of map sheet 21A/09 (Corey, 1990). Contacts with metasedimentary country rocks, where observed (e.g. near Upper New Cornwall and Falkland ridge; Horne, 1993), are sharp and intrusive. Contacts between

coarse-grained leucomonzogranite units and other granitic rock types in the batholith are mostly intrusive, with the exception of the contact with the Harrietsfield muscovite-biotite monzogranite and the Sandy Lake biotite monzogranite in the Halifax Pluton (MacDonald and Horne, 1987) and several Panuke Lake fine-grained leucomonzogranite bodies in the New Ross pluton (Corey, 1990) which are gradational. Coarse-grained leucomonzogranite units contain few xenoliths, even where units are in direct contact with metasedimentary country rocks. In general, xenoliths in these units have microgranitoid textures, commonly with feldspar porphyroblasts (megacrysts?; Plate 3.8), and do not resemble metasedimentary rocks of the Meguma Group.

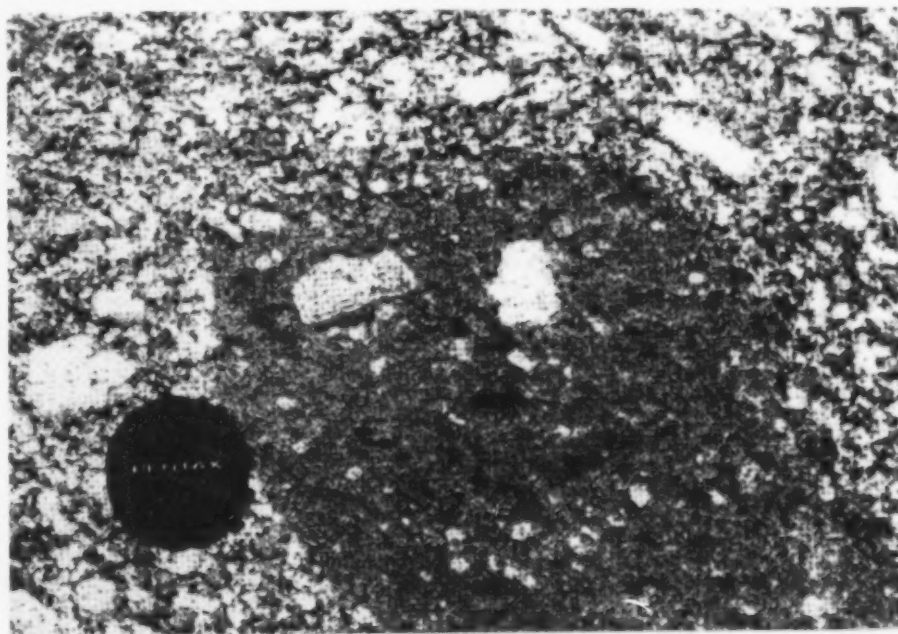


**Plate 3.8** Microgranitoid xenolith with alkali feldspar porphyroblasts (megacrysts?) in an outcrop of Halifax Peninsula coarse-grained leucomonzogranite (MacDonald and Horne, 1987).

### 3.1.5 Fine-Grained Leucomonzogranite

Fine-grained leucomonzogranite units are mostly buff, orange, pink and whitish-grey in colour, which generally reflect the variable degrees of hematization, albitization and K-feldspathization. Localized areas with moderate to intense hematization have intense reddish colouration. Most units are fine- to medium-grained with equigranular (Plate 3.1e) or porphyritic (Plate 3.1f,g) texture. Other common textures include: fine-grained equigranular (Plate 3.1d) or aplitic (i.e. saccharoidal); fine- to medium seriate; and coarse-grained pegmatitic (Plate 3.1h).



Many individual bodies, that range in size from 1-10 km<sup>2</sup>, have very uniform equigranular or porphyritic textures and are denoted with separate patterns in Figure 2.3 (in pocket in back). Other fine-grained leucomonzogranite bodies typically have a wide range of textures, many of which may be present within a single outcrop, such as in the Tantallon leucomonzogranite of the Halifax Pluton (MacDonald and Horne, 1987). These bodies are unpatterned in Figure 2.3. Coarse-grained leucomonzogranite typically contains 2-7% biotite (with accessory apatite, zircon, monazite, xenotime, ilmenite), 3-13% muscovite and trace amounts of cordierite and andalusite. Fine-grained leucomonzogranite is distinguished from most other rock types by its finer grain size, and from leucogranite by its high biotite content.

Fine-grained leucomonzogranite units comprise approximately 6.8% of the batholith. The majority of the fine-grained leucomonzogranite units occur in Stage II plutons, particularly the larger bodies (i.e. >2-3 km<sup>2</sup>), although small (<1 km<sup>2</sup>) bodies occur in all Stage I plutons. The "type section" for the variable-textured fine-grained leucomonzogranite is along Highways #3 and #103 near Fourteen Mile House and to the west near Upper Tantallon on map sheet 11D/12 (MacDonald and Horne, 1987). The "type section" for equigranular-textured fine-grained leucomonzogranite is along Highway #103, 2-4 km east of the intersection with Highway #14, at the margin of the New Ross pluton on map sheet 21A/09 (Corey, 1990). The "type section" for porphyritic-textured fine-grained leucomonzogranite is along Highway #14, approximately 2 and 4 km south of Upper Vaughan (Ham, 1990). Contacts with metasedimentary country rocks, where observed, are sharp and intrusive (e.g. near Ferguson's Cove, MacDonald and Horne, 1987 Plate 3.9; on Caribou Lake, Horne, 1993; at Inglisville, MacDonald and Ham, 1994b). Contacts between fine-grained leucomonzogranite units and other granitic rock types in the batholith are mostly intrusive (Plate 3.10), with the exception of the contact with several Panuke Lake fine-grained leucomonzogranite bodies in the New Ross pluton which are gradational. Corey (1990) interpreted these bodies as chilled(?) textural equivalents of the adjoining coarse-grained leucomonzogranite. Fine-grained leucomonzogranite units contain few xenoliths, even where units are in direct contact with metasedimentary country rocks.

### 3.1.6 Muscovite Leucogranite

Leucomonzogranite units are mostly buff, orange, pink and whitish-grey in colour, which



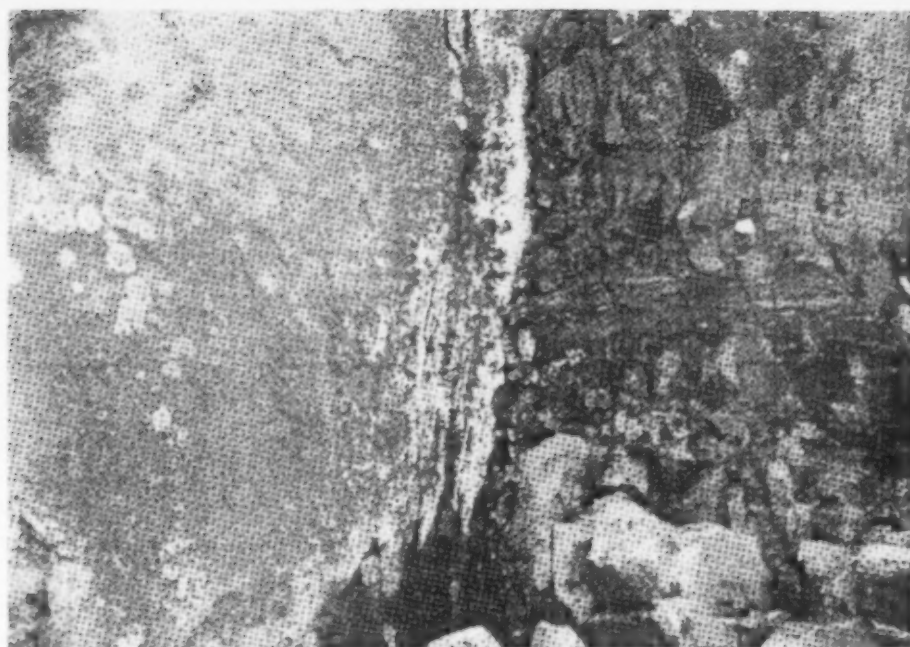


**Plate 3.9** Steeply-dipping intrusive contact between the Tantallon fine-grained leucomonzogranite and finely bedded slates of the Halifax Formation near Ferguson's Cove (MacDonald and Horne, 1987). Note the lack of deformation of country rocks and the absence of xenoliths in the leucomonzogranite. Width of photo is approximately 3 metres.

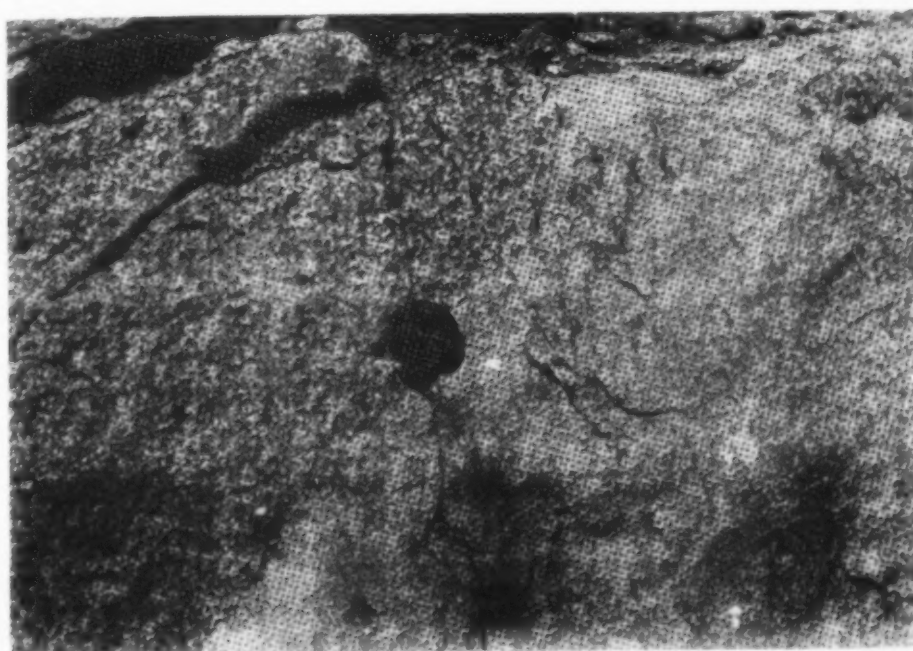


**Plate 3.10** Sharp intrusive contact between the Tantallon fine-grained leucomonzogranite and the Sandy Lake biotite monzogranite, Halifax Pluton (MacDonald and Horne, 1987). Field relations elsewhere in the pluton indicate that the Tantallon unit intruded the Sandy Lake unit. Note the lack of a chilled margin in the leucomonzogranite.

generally reflect the variable degrees of hematization, albitization and K-feldspathization. Localized areas with moderate to intense hematization have intense reddish colouration. Most units are fine- to medium-grained with equigranular or porphyritic texture. Other common textures include: fine-grained aplitic (i.e. saccharoidal); fine- to medium-grained seriate; and coarse-grained pegmatitic. Several leucogranite bodies have somewhat uniform textures being mostly equigranular and/or porphyritic. In contrast, the Murphy Lake leucogranite which is exposed in three bodies in the east-central part of map sheet 21A/15, characteristically shows a wide range of textures, many of which may be present within a single outcrop (Plate 3.11; MacDonald and Ham, 1992). Leucogranite units typically contains 0-2% biotite, 3-28% muscovite, 0-8% topaz, 0-2% andalusite and trace amounts of cordierite. Leucogranite is distinguished from most other rock types by its finer grain size, and from leucomonzogranite by its low biotite content.



**Plate 3.11** Typical boulder of Murphy Lake Leucogranite (MacDonald and Ham, 1992) showing characteristic textural heterogeneity with alternating aplitic and pegmatitic layers.

Leucogranite units comprise approximately 0.7% of the batholith and are restricted to Stage II plutons with the exception of one of the Murphy Lake Leucogranite bodies (MacDonald and Ham, 1992) and the Walsh Brook Leucogranite (Corey, 1987) which are hosted by biotite granodiorite of Stage I plutons. The "type section" for leucogranite is along a series of secondary

roads between Lake Lewis and South Canoe Lake and along the adjoining New Ross-Vaughan Road on map sheet 21A/16 (West; Ham, 1990). The "type section" for texturally-variable leucogranite is along a series of secondary roads southeast of Aylesford Lake in the east-central part of map sheet 21A/15 (MacDonald and Ham, 1992). Contacts with metasedimentary country rocks, where observed, are sharp and intrusive (e.g. in the Open Pit Mine at East Kemptville; Ham and MacDonald, 1994). Contacts between leucogranite units and other granitic rock types in the batholith are entirely sharp and intrusive. Leucogranite units are devoid of xenoliths, even where units are in direct contact with metasedimentary country rocks.

### 3.2 Plutons

The 49 map units in the batholith have been grouped into 13 plutons using the criteria outlined in Chapter 2 (Fig. 3.1). These plutons have been grouped into two stages on the basis of field relations and compositions. Stage I plutons are mainly comprised by biotite granodiorite and biotite monzogranite with minor amounts of fine-grained leucomonzogranite. In contrast, Stage II plutons are primarily made up of muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite with minor amounts of muscovite leucogranite and/or biotite granodiorite and biotite monzogranite. Exposed contacts between Stage I and II plutons are rare, however, when observed these contacts were ubiquitously sharp and intrusive with the early Stage I plutons invariably intruded by later Stage II plutons. This general observation is consistent with the observations of McKenzie and Clarke (1975) and Smith (1979). The salient geological features of Stage I and II plutons are given in Table 3.2 and summarized in the following section.

Stage I plutons range in size from 230 to 2460 km<sup>2</sup> whereas Stage II plutons are generally smaller, on average, and range in size from 30 to 1060 km<sup>2</sup>. The proportions of rock types in Stage I plutons include: 0-100% biotite granodiorite; 0-100% biotite monzogranite; and trace-1% fine-grained leucomonzogranite. The proportions of rock types in Stage II plutons include: 0-100% muscovite-biotite monzogranite; 0-93% coarse-grained leucomonzogranite; 0-28% fine-grained leucomonzogranite; 0-10% leucogranite. Four out of five Stage I plutons exhibit normal and/or reverse compositional zoning that is manifest by changes in modal mineralogy and major, trace and isotopic geochemistry (see discussions below). The Cloud Lake Stage I pluton does not show obvious evidence of zoning. In contrast, only three of the eight Stage II plutons display normal and/or reverse zoning.

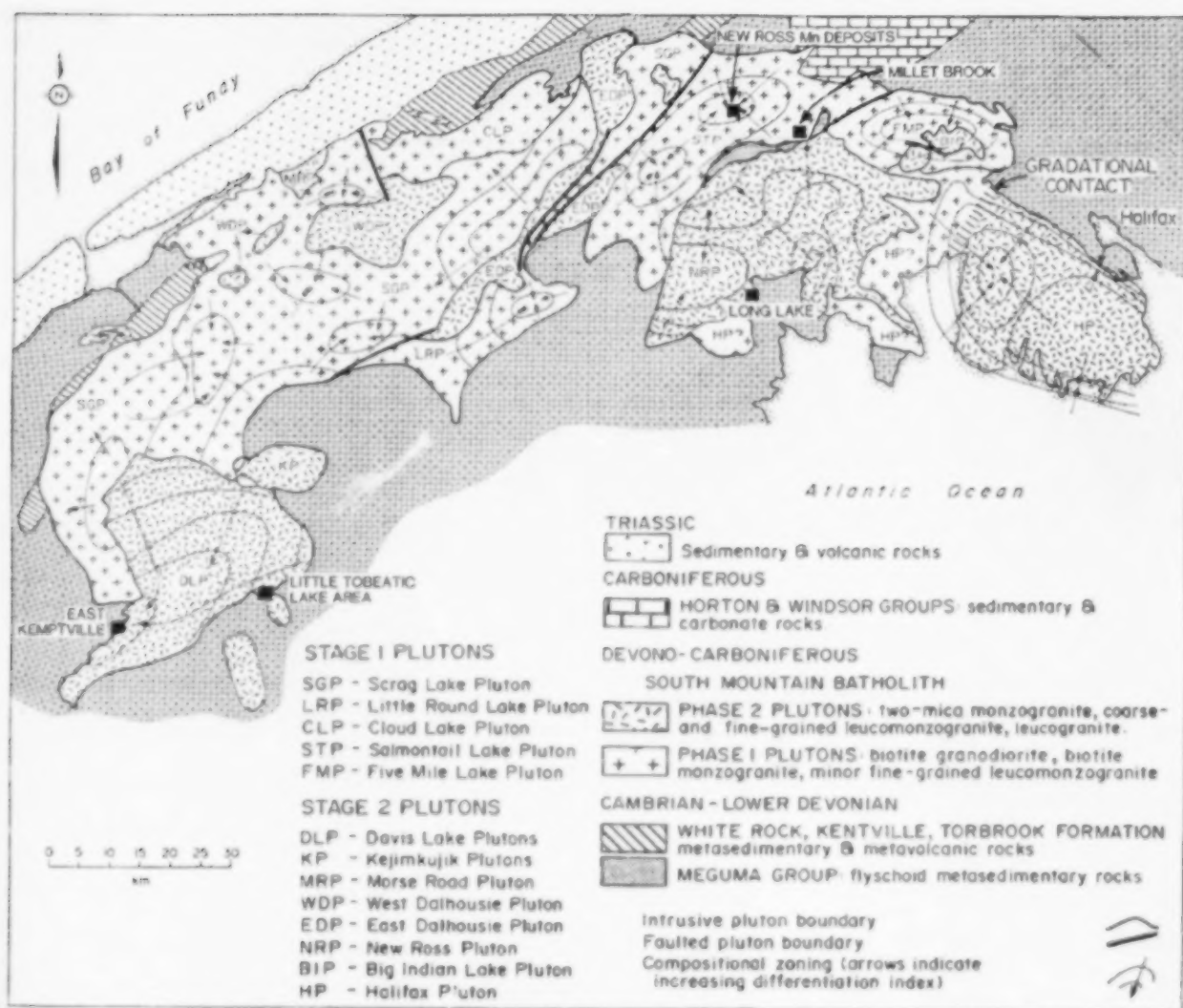


**Figure 3.1** Geological map of the South Mountain Batholith showing the location of the five Stage I and eight Stage II plutons. Heavy lines at pluton boundaries indicate faulted contacts whereas thinner lines indicate predominantly intrusive contacts (may be gradational in part). Thin lines within the individual plutons indicate compositional isopleths that were determined from point counting stained rock slabs and/or geochemical data. Arrows indicate increasing differentiation index. Areas of both normal and reverse compositional zoning (differentiation index increases and decreases, respectively, toward the core of the pluton) are evident in some Stage I and II plutons. In fact, several plutons such as the Halifax and New Ross plutons, have both normal and reverse compositional zoning.

Stage I plutons have elliptical shapes with the long axes oriented to the northeast. In contrast, most Stage II plutons are roughly circular or irregular in shape. Both the East Dalhousie and the southwestern part of the Davis Lake Stage II plutons are narrow and somewhat "dyke-like" in shape. All Stage I and five of the eight Stage II plutons are partially bounded by faults.



Table 3.2. Summary of selected features of Stage I and Stage II plutons.

| PLUTON NAME                                                                                                                 | AREA (km <sup>2</sup> ) | ROCK TYPES (% of Pluton)                             | ZONING | SHAPE                | ORIENTATION | FAULT BOUNDED | PRIMARY FEATURES                                               | COMMENTS                                                        |
|-----------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------------------------------------|--------|----------------------|-------------|---------------|----------------------------------------------------------------|-----------------------------------------------------------------|
| <b>EARLY</b>                                                                                                                |                         |                                                      |        |                      |             |               |                                                                |                                                                 |
| <i>Stage 1 Plutons - dominantly biotite monzogranite and biotite monzogranite with minor fine-grained leucomonzogranite</i> |                         |                                                      |        |                      |             |               |                                                                |                                                                 |
| Scrag Lake WEST                                                                                                             | 2460                    | BMG(79); BGD(21)                                     | N & R  | elongate             | NE          | partially     | well developed N & NE megacryst alignment                      | several compositional "cores"                                   |
| Little Round Lake                                                                                                           | 230                     | BMG(=100)                                            | R      | elongate             | NE          | partially     | well developed NE megacryst alignment                          |                                                                 |
| Cloud Lake                                                                                                                  | 280                     | BMG(95); BGD(5)                                      | None   | elongate             | NE          | partially     | pervasive NE & E megacryst alignment                           | locally developed E-trending biotite foliation                  |
| Salmetail Lake                                                                                                              | 580                     | BMG(91); BGD(8); FGLMG(1)                            | N      | elongate             | NE          | partially     | weakly developed NE megacryst alignment                        | two compositional "cores"                                       |
| Five Mile Lake EAST                                                                                                         | 270                     | BGD(=100)                                            | R      | elliptical           | E           | partially     | moderate megacryst alignment - erratic orient.                 |                                                                 |
| <b>LATE</b>                                                                                                                 |                         |                                                      |        |                      |             |               |                                                                |                                                                 |
| <i>Stage 2 Plutons - dominantly muscovite biotite monzogranite and leucomonzogranite with minor ultra leucogranite</i>      |                         |                                                      |        |                      |             |               |                                                                |                                                                 |
| Davis Lake WEST                                                                                                             | 870                     | CGLMG(93); FGLMG(3); BGD(4); BMG(1); MBMG(1); LG(=1) | N      | circular & elongate* | *NE         | *partially    | well developed N & NE megacryst alignment                      | *elongate portion partially bounded by intense shearing         |
| Kepimikuk                                                                                                                   | 80                      | MBMG(=100)                                           | None   | roughly circular     | N/A         | No            | no consistent alignment                                        |                                                                 |
| Moore Road                                                                                                                  | 30                      | CGLMG(55); MBMG(45)                                  | None   | roughly circular     | N/A         | No            | no consistent alignment                                        | bands of MBMG along E - W margins suggests normal zoning        |
| West Dalhousie                                                                                                              | 220                     | MBMG(=100)                                           | None   | roughly circular     | N/A         | partially     | well developed megacryst alignment - erratic orientation       | unique megacryst-rich texture with "banded" biotite             |
| East Dalhousie                                                                                                              | 310                     | CGLMG(52); FGLMG(34); LG(10); MBMG(4)                | None   | narrow dyke-like     | NE          | predominantly | locally developed megacryst alignment - erratic orientation    | emplaced along major structure                                  |
| Big Indian Lake                                                                                                             | 40                      | CGLMG(81); FGLMG(17); BMG(2)                         | None   | circular/irregular   | N/A         | partially     | no consistent alignment                                        | obscure metamorphic garnet                                      |
| New Ross                                                                                                                    | 870                     | CGLMG(99); FGLMG(20); MBMG(12); LG(2)                | N & R  | roughly circular     | N/A         | partially     | megacryst alignment defines weakly-developed circular patterns | overall reverse rotation                                        |
| Halifax EAST                                                                                                                | 1080                    | CGLMG(38); MBMG(33); BMG(13); FGLMG(12); BGD(4)      | N & R  | roughly circular     | N/A         | no            | megacryst alignment defines weakly-developed circular patterns | gradational contact with BMG to west (separate Phase 1 pluton?) |

**EXPLANATION:**

ROCK TYPES - BGD - biotite monzogranite; BMG - biotite monzogranite; MBMG - muscovite biotite monzogranite; CGLMG - coarse-grained leucomonzogranite; FGLMG - fine-grained leucomonzogranite; LG - ultra-leucogranite.

ZONING - N - normal; R - reverse

ORIENTATION - refers to direction of long axis of pluton (if applicable); N/A - not applicable

Prominent northeast-trending primary flow features (schlieren, parallel alignment of megacrysts/xenoliths) are common in Stage I plutons whereas they are variably developed (non-existent to strong) with erratic or concentric orientations in Stage II plutons.

Detailed descriptions of the geology of the Scrag Lake and Halifax Plutons which are representative of the Stage I and II plutons respectively. For more complete description of the rocks of the other plutons the reader is referred to the fourteen geological maps with marginal notes that are outlined in Figure 2.1.

### 3.2.1 Scrag Lake Stage I Pluton

The Scrag Lake Pluton (Fig. 3.1) is the largest Stage I pluton in the batholith (2460 km<sup>2</sup>). It forms much of the western end of the batholith and is located on NTS map sheets 21A/04, /05, /06, /10, /11, /12, /14 and /15. It is elliptical in shape with the long pluton axis oriented to the northeast. Field relations are described by several workers (see Table 2.1 for references).

The Scrag Lake Pluton is primarily made up of megacrystic **biotite monzogranite** (79%)



which is distributed throughout the pluton. Contacts with the metasedimentary and metavolcanic country rocks are ubiquitously sharp and intrusive. Modal amounts of biotite range from 10-17% whereas muscovite and cordierite are only present in trace-1%. Most rocks plot in the monzogranite field of Streckeisen (1976), however, some samples plot in the granodiorite field but are not abundant enough to justify separate designation and have been grouped with monzogranitic rocks. The next most abundant rock type in the Scrag Lake Pluton is megacrystic **biotite granodiorite** which comprises approximately 21% of the pluton. Granodiorite occurs mainly along the western margin and the eastern end of the pluton, and between the East Dalhousie and West Dalhousie plutons. Contacts with biotite monzogranite are ubiquitously gradational, in fact, it was not possible to establish contacts in field because of a lack of changes in texture or grain size. Contacts were consequently defined on the basis of proportions of quartz-alkali feldspar-plagioclase, as determined by point counting of rock slabs. Modal amounts of biotite range from 15- > 25% whereas muscovite and cordierite are only present in trace amounts. Most rocks plot in the granodiorite field of Streckeisen (1976), however, some samples plot in the monzogranite field but were grouped with granodiorite.

Numerous small bodies (<1-2 km<sup>2</sup>) of fine-grained leucomonzogranite which constitute <0.1% of the pluton occur throughout the granodiorite and monzogranite units. Contacts are, where observed, sharp and intrusive. Leucomonzogranite rocks vary somewhat in composition but generally are within the description outlined above.

Contacts between the Scrag Lake and other Stage I plutons are both faulted, as for the Little Round Lake, Salmontail Lake and parts of the Cloud Lake Plutons, and intrusive as for part of the Cloud Lake pluton. There was no indication of chilling, for example reduction in grain size, in either the Scrag Lake or Cloud Lake plutons near the intrusive contact. However, schlieren banding in the Cloud Lake pluton near the contact may indicate that it was emplaced and crystallized after the Scrag Lake Pluton. The contacts between Stage I and II plutons, including Davis Lake, Kejimikujik, West Dalhousie, Morse Road and East Dalhousie plutons, were always noted or inferred to be sharp and intrusive. No evidence of chilling, such as reduction of grain size, was noted at any of the intrusive contacts. However, the presence of inclusions of granodiorite and monzogranite in the East Dalhousie Pluton indicates that it post-dates the Scrag

Lake Pluton. Most other Stage II plutons truncate compositional patterns in the Scrag Lake pluton indicating that they were also emplaced subsequent to crystallization of the Scrag Lake Pluton.

The Scrag Lake Pluton displays both normal and reverse compositional zoning (Fig. 3.1) which is readily discernable using modal proportions of biotite and, to a lesser extent, the proportion of quartz-alkali feldspar-plagioclase. Using modal information, Horne et al. (1991) and MacDonald et al. (1992) concluded that there were at least four normally zoned "centres" and one reversely zoned "centre" in the pluton. Normally zoned "centres" are tentatively interpreted as representing *in situ* fractionation. In general, most of the pluton is normally zoned, with the most highly fractionated rocks in the core regions of the pluton. The origin of the reversely zoned "centre" is not clear at present.

Primary flow features, including parallel alignment of alkali feldspar megacrysts and xenoliths and schlieren banding, are mainly oriented northeast in the central and eastern parts of the pluton and north to north-northeast oriented to the southwest. Interestingly these orientations mirror the structural trends in the country rocks, which will be discussed further in Chapter 4.

### 3.2.2 Halifax Stage II Pluton

The Halifax Pluton (Fig. 3.1) forms the easternmost part of the batholith and is located on NTS map sheets 11D/05 and 11D/12. It is sub-circular in shape and is the largest Stage II pluton (1060 km<sup>2</sup>) in the batholith. MacDonald and Horne (1987) described the field relations for pluton and MacDonald and Horne (1988) reported the results of a detailed petrographic and geochemical study of the Halifax Pluton.

The Halifax Pluton comprises a zoned sequence of megacrystic map units that were intruded by a sequence of fine-grained leucomonzogranite. The zoned sequence consists of: 1) a narrow band (<1-3 km wide) of slightly megacrystic **biotite granodiorite** that extends along the northeastern margin of the pluton and is in sharp intrusive contact with the metasedimentary rocks of the Meguma Group. This unit, which constitutes 4% of the pluton, has 12- > 15% biotite and trace amounts of muscovite and cordierite; 2) megacrystic **biotite monzogranite** that forms narrow bands (1-3 km wide) along the southern margin of the pluton and adjacent to the granodiorite to the north. Contacts between this unit and the biotite granodiorite are invariably gradational. Biotite monzogranite, which makes up approximately 13% of the pluton, contains 10-

12% biotite and trace-1% muscovite and cordierite; 3) megacrystic **coarse-grained leucomonzogranite** which is the dominant rock type in the pluton (38%) forms a large body in the western part of the pluton and narrow (1-3 km wide) bands along the southern and northern margins of the pluton. Contacts with biotite monzogranite and biotite granodiorite were noted to be both gradational and intrusive. This unit contains 2-6% biotite, 2-5% muscovite. Cordierite or pinite/chlorite/muscovite pseudomorphs, makes up 0-5% of the mode and is most abundant in the narrow bands along the pluton margins and increases toward the adjacent muscovite-biotite monzogranite; 4) megacrystic **muscovite-biotite monzogranite** which is the dominant rock type in the eastern part of the pluton and constitutes 33% of the pluton. Contacts with the adjacent leucomonzogranite are both gradational and intrusive. This unit is in both gradational and intrusive contact with the adjacent coarse-grained leucomonzogranite. This unit has 8-10% biotite 1-2% muscovite. Cordierite constitutes 0-5% of the mode and is most abundant along the southern and northern unit margins. No evidence of chilling, such as reduction of grain size, was noted at any of the intrusive contacts. On the basis of the modal mineralogy the outer part of the sequence (granodiorite to leucomonzogranite) is normally zoned whereas the inner part (leucomonzogranite-muscovite-biotite monzogranite) is reversely zoned.

A second sequence of fine-grained leucomonzogranite which constitutes approximately 12% of the pluton occurs as a body in the northwestern part of the map sheet (approx. 4 x 20 km) and numerous small (< 1-5 km<sup>2</sup>) throughout the pluton. Most rocks are fine- to medium-grained with equigranular or porphyritic textures although some pegmatitic and aplitic textures were also noted. Contacts with the zoned sequence of megacrystic units are ubiquitously sharp and intrusive. Modal mineralogy consists of 2-5% biotite, 2-5% muscovite (locally up to 10%) and trace-2% cordierite. This sequence of rocks cross-cuts the zoned sequence although in general fine-grained leucomonzogranite is most abundant in the most "evolved" part of the coarse-grained leucomonzogranite and may have a genetic relationship.

Primary flow features in the Halifax Pluton define a crude circular pattern that mirrors the margin of the pluton and are in sharp contrast to the northeast orientations for the primary flow features in the Scrag Lake Pluton. The significance of this will be discussed in Chapter 4.

MacDonald and Horne (1988) present a detailed discussion of the possible mechanisms for

formation of the compositional zonation in the Halifax Pluton based upon field, mineralogical and geochemical information. They concluded that the zoned sequence of the pluton formed by a combination of sidewall fractional crystallization and vertical stratification caused primarily from a less-dense rising "boundary layer" during fractionation within a single magma chamber (Figure 3.2; see MacDonald and Horne (1987) for more detail). The later-staged fine-grained leucomonzogranites were presumably generated, at least in part, by fractionation of the zoned sequence.

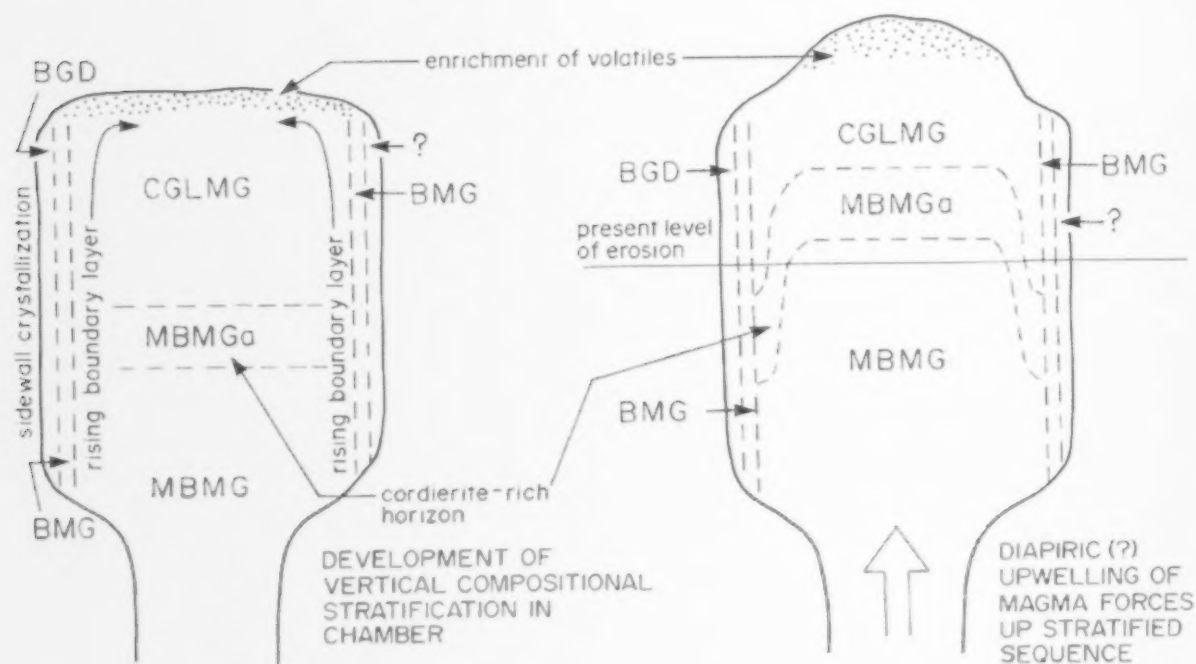


**Figure 3.2** A model for the formation of the zonation in the Halifax Pluton (after MacDonald and Horne, 1988). Crystallization commences along the cool metasedimentary walls (sidewall crystallization) followed by the development of a fractionated 'boundary layer' because of slow diffusion rates in the melt. This layer is less dense than adjacent melt and rises to apical portions of the magma chamber causing vertical stratification of the central magma. Cordierite primarily crystallizes in a discrete compositional layer in the sequence. Subsequent influx of magma into lower portions of the chamber 'warps' the stratified sequence which, after erosion to present level, yields the observed outcrop pattern (Fig. 2.3 in pocket at back). Rock units include: BGD - biotite granodiorite; BMG - biotite monzogranite; MBMG - muscovite-biotite monzogranite; MBMGa - cordierite-rich muscovite-biotite monzogranite; CGLMG - coarse-grained leucomonzogranite

Delineation of the western margin of the Halifax Pluton is somewhat problematic. MacDonald and Horne (1988) focused on the portion of the pluton that occurs north and west from the head of St. Margaret's Bay (Fig. 2.3). However a large area of biotite monzogranite

extends from their study area westward to the boundary of the New Ross pluton and northwest to the margin of the Five Island Pluton. There is no clear boundary between this biotite monzogranite and the Sandy Lake unit and subsequently these units have been grouped together. It is possible that the western biotite monzogranite is a separate Stage I pluton. Conversely if this unit is part of the Halifax Pluton, then bodies of Sandy Lake monzogranite in the New Ross Pluton indicates that the Halifax Pluton predated the New Ross Pluton.

### 3.3 Mafic Porphyry

Mafic porphyry is a volumetrically small (approx 0.07%) rock type in the batholith. However, some mafic porphyry bodies are among the most "primitive" in composition in the batholith, have several features that are unlike the above major rock types and thus merit investigation. Individual bodies display a wide range of textures and modal mineralogy which are summarized in Table 3.3. Mafic porphyry are mainly medium- to dark grey to brownish-grey in colour. Rocks are primarily fine- to coarse-grained and have porphyritic texture with phenocrysts of quartz, plagioclase and alkali feldspar. Mafic porphyry bodies mainly range from granodiorite to monzogranite in composition although some bodies plot in the tonalite compositional field of Streckeisen (1976). As a group, mafic porphyry rocks contain a wide range of biotite (10-32%). However it should be stressed that individual bodies may have either narrow modal ranges, such as at Cloud Lake (15-20%) or wide ranges, as noted in the Boot Lake body (19-32%; Table 3.4) which are both exposed on map sheet 21A/15 (MacDonald and Ham, 1992). Biotite characteristically contains poikilitic inclusions of apatite, zircon, monazite and ilmenite. Several mafic porphyry bodies contain trace-2% reddish coloured (almandine?) garnet. Muscovite is only present in trace amounts. The Boot Lake mafic porphyry contains trace-2% andalusite.

Mafic porphyry bodies were noted in both Stage I and II plutons. Several bodies are restricted to marginal regions of biotite granodiorite and biotite monzogranite of Stage I plutons, such as near Saturday Lake on map sheet 21A/10 (Horne, 1993) and in the Boot Lake unit on map sheet 21A/15 (MacDonald and Ham, 1992). These units have sharp intrusive contacts with the country rocks and both gradational and intrusive contacts with the adjoining granitoid rocks. Other mafic porphyry units are situated away from country rock contacts, such as at Lequille on map sheet 21A/11 (Corey and Horne, 1994b). Contacts with the adjacent granitoid units are sharp and intrusive. It is difficult to give a "type section" for a rock type that has such variation, however,



Table 3.3. Description of mafic porphyries from the South Mountain Batholith.

| Map Sheet | Name/Location               | Rock Type | Biotite | Garnet     | Comments                                                                                   |
|-----------|-----------------------------|-----------|---------|------------|--------------------------------------------------------------------------------------------|
| 11D/05    | Sambro                      | BMG/BGD   | > 15%   | -          | "Sinuous" contact with CGLMG - magma mixing (?)                                            |
| 21A/10    | Saturday Lake               | BGD       | 15-20%  | -          | Marginal (chilled?) phase of BMG; Mo-bearing quartz veins                                  |
| 21A/11    | Leguille                    | BGD       | > 20%   | trace - 1% | Intensive contact with BGD                                                                 |
| 21A/15    | Boot Lake                   | BGD/BTN   | 19-32%  | trace - 2% | Marginal phase of BGD; partial melting of metasediments(?); "wispy" bands in country rocks |
| 21A/15    | Cloud Lake                  | BGD       | 15-20%  | -          | Isolated bodies in BMG                                                                     |
| 21A/15    | Burnt Dam Flowage           | BGD       | 15-20%  | trace      | Marginal phase of BMG at country rock contact                                              |
| 21A/16    | Big St. Margaret's Bay Lake | BMG       | 10-18%  | -          | "Sinuous" contact with FGLMG - magma mixing(?)                                             |
| 21A/16    | Powerline                   | BMG       | 12-20%  | -          | Isolated plugs in BGD                                                                      |

## Explanation:

Rock Type: BMG - biotite monzogranite; BGD - biotite granodiorite; BTN - biotite tonalite; CGLMG - coarse-grained leucomonzogranite; FGLMG - fine-grained leucomonzogranite

the excellent exposures at the Lequille intersection of the #103 highway has most of the features found in most bodies. This body is granodiorite in composition, has very high biotite content (>20%) and contains up to 1% garnet crystals. In addition, a sharp intrusive contact with the adjacent Lequille granodiorite unit is exposed in the road cut. Mafic porphyry rocks have the highest proportion of xenoliths of any rocks in the batholith, with the exception of limited areas of granodiorite, chiefly near country rock contacts. The majority of xenoliths are similar, at least macroscopically, to metasedimentary rocks of the Meguma Group.

In addition to the mappable bodies denoted on Figure 2.3 (in pocket at back), numerous "xenoliths" of mafic porphyry were noted throughout the batholith. These are most common in granodiorite but were also noted in biotite and biotite-muscovite monzogranite units. The "xenoliths" also contain metasedimentary xenoliths, despite the fact that they were commonly observed in central regions of the batholith, such as shown in Plate 3.2. The author favours an explanation whereby the mafic porphyry xenolith represents a marginal phase of the Halifax Pluton, perhaps from apical portions of the Sandy Lake unit, that: 1) incorporated abundant metasedimentary xenoliths; 2) crystallized at the pluton margin, thus trapping the metasedimentary xenoliths; 3) was "spalled off" of the marginal zone and "sank" because of higher specific gravity (Miller and MacDonald, 1992); and 4) was trapped in its present location in the Sandy Lake monzogranite during crystallization.

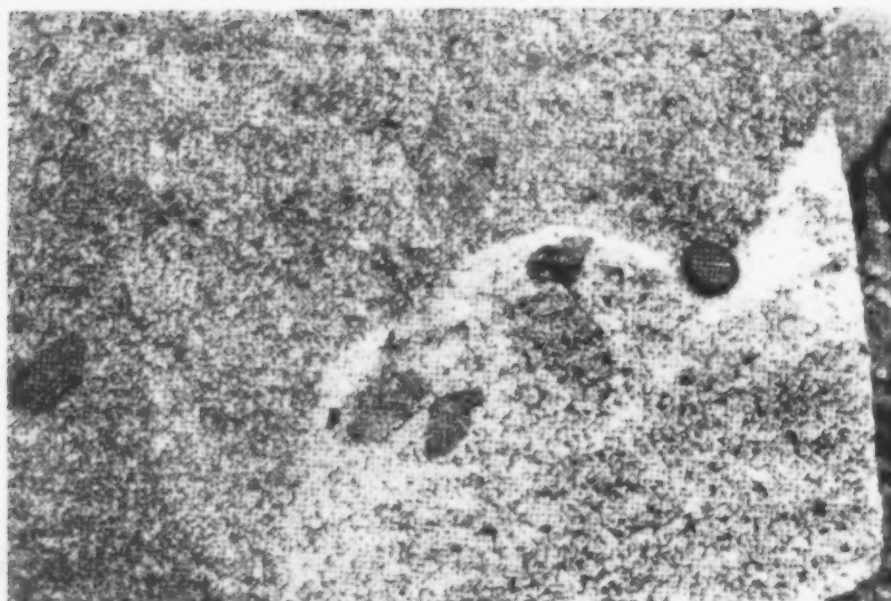


**Plate 3.12** Mafic porphyry "xenolith" in an outcrop of Sandy Lake biotite monzogranite from near the margin the Halifax Pluton. Note that 'fresh' metasedimentary xenoliths from the Meguma Group country rocks occur in the mafic porphyry xenolith and are concentrated, along with alkali feldspar megacrysts, in the biotite monzogranite. This is interpreted as concentration of solid components at the bottom of the mafic porphyry xenolith as it sank in the biotite monzogranite melt. The mafic porphyry presumably formed as an early, mafic-rich, marginal phase to the Halifax Pluton that was subsequently incorporated as an autolith by the biotite monzogranite melt.

The contacts between mafic porphyry bodies at Sambro (MacDonald and Horne, 1987) and Big St. Margaret's Bay Lake (Ham and Horne, 1987; Dewolfe, 1994), and the adjoining coarse- and fine-grained leucomonzogranite units respectively, are sharp and intrusive. However, contacts are commonly sinuous or ragged and lack any chilled contacts (Plate 3.2). The morphology of these contacts are markedly different from the angular granite/granite contacts commonly noted throughout the batholith. Dewolfe (1994) noted lobate contacts which he interpreted to reflect mingling of mafic porphyry and leucomonzogranite melts in the Big St. Margaret's Bay Lake area. Similarly, the curving shape of contacts in the Sambro area would not be predicted if one of the units were completely crystalline and therefore these features are tentatively interpreted as representing mingling of two compositionally dissimilar granitoid melts.

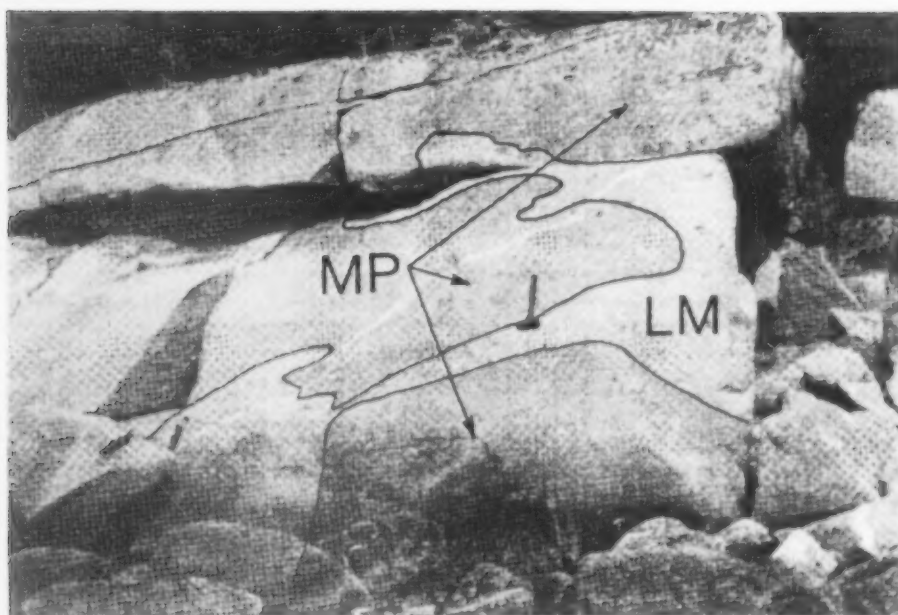


Plate 3.13 Geological contact between mafic porphyry and coarse grained leucomonzogranite at Sambro on map sheet 11D/05 (MacDonald and Horne, 1987). The sinuous morphology and lack of chilling in either unit is consistent with mixing of compositionally dissimilar granitoid melts.

The contacts between the Boot Lake mafic porphyry and the adjoining Halifax Formation slates are very irregular and "wispy" as shown in Plate 3.3. Based entirely on field evidence it is difficult to determine whether the development of mafic porphyry along this contact results from partial melting of metasediments or chilling of the host granodiorite unit with a high degree of country rock assimilation. This will be further discussed in Chapter 6, in light of geochemical information.

### 3.4 Dyke Rocks

Dyke rocks consist of, in decreasing order, aplite, pegmatite, composite aplite/pegmatite and minor amounts of granitoid units. Aplite dykes, by definition, are fine grained and have sugary (i.e. saccharoidal) texture whereas pegmatite dykes have very coarse grain size with some crystals to 20-30 cm, and commonly have graphic texture. The majority of the other dykes are fine grained with equigranular texture although minor medium- or coarse-grained phenocrysts (mostly quartz and feldspar) may occur. Composite dykes have both "aplite" and pegmatite arranged in alternating bands that are mostly parallel or subparallel to the dyke margins (Plate 3.14).

The late staged dykes in the batholith have a wide compositional range which is manifest as highly variable mineralogy. The essential mineralogy of dyke rocks consists of quartz, alkali

feldspar, albitic plagioclase, muscovite (3-25%) and biotite (trace-10%). Dyke rocks may also contain spessartine-rich garnet (up to 5%), tourmaline (mostly in pegmatite or pegmatite segregations in composite dykes), fluorite and andalusite (up to 5% in some equigranular leucogranite dykes). In addition, some pegmatite dykes reportedly contain columbite, tantalite, tapiolite, cassiterite, wolframite and beryl (Farley, 1979; O'Reilly et al., 1982).

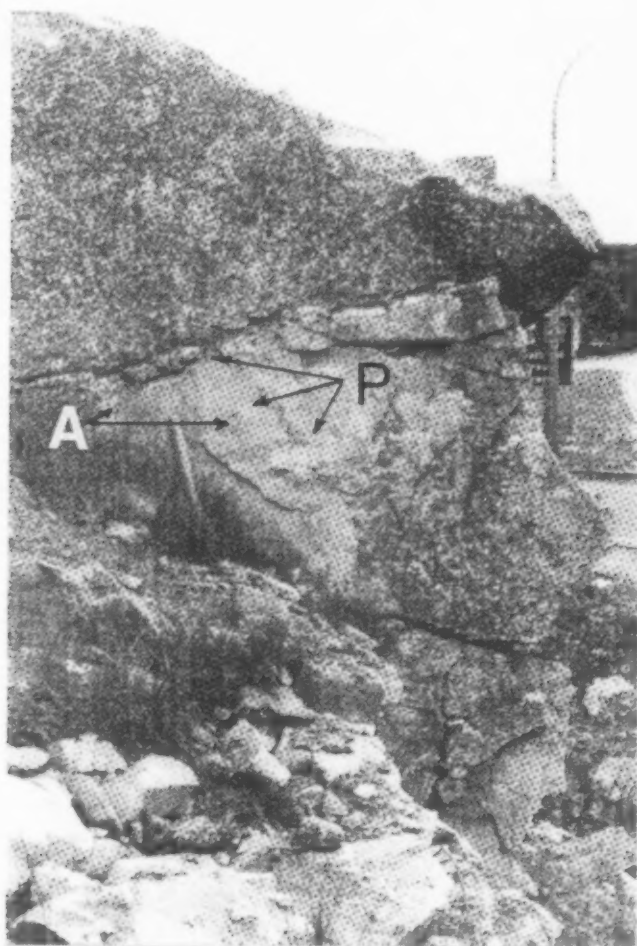


**Plate 3.14** Composite aplite/pegmatite dyke in an outcrop of Sandy Lake biotite monzogranite along the northern margin of the Halifax Pluton. Note the alternating layers of aplite and pegmatite that are parallel to the margin of the dyke. Hammer handle is 40 cm long.

Dykes occur in all rock types, in both Stage I and II plutons, from the least evolved biotite granodiorite and mafic porphyry to the most evolved leucogranite. No attempt was made to quantify the exact proportion of dyke rocks in each rock type as part of the mapping project.

However, empirical evidence suggests that dykes are somewhat evenly distributed throughout the entire batholith. It should be stressed that local dyke concentrations were noted within some units, such as in parts of the New Ross Pluton on map sheet 21A/16 (Ham and Horne, 1987). Dyke rocks, by their nature, have sharp intrusive contacts and post-date the crystallization of the host rocks. In several locations throughout the batholith dyke rocks were observed to cross-cut metasedimentary and granitoid xenoliths (Plate 3.15) and primary flow features, such as schlieren bands and megacrysts-rich pods. Most dykes have linear contacts, however, many have curved contacts and sinuous orientations, particularly the flat-lying and shallow-dipping varieties. Dyke thicknesses range from a few centimetres to several metres. Most dykes can only be traced for several metres across individual outcrop, however, a few dykes could be traced for several hundred metres. In fact, there may be a complete continuum from large dykes to small plugs of fine grained leucomonzogranite. Information pertaining to dykes, that was collected during geological mapping, included: dyke rock type; grain size and texture; modal mineralogy; dyke thickness and orientation; and the presence of internal structure such as textural and mineralogical banding. This information is graphically displayed on each of the fourteen 1:50,000 scale geological maps.

Horne et al. (1988, 1992) compiled the orientation data for dykes as part of a structural study of the entire batholith. It should be noted that the vast majority of outcrop inspected during mapping were smooth "glacial pavement" along road sides or rounded (i.e. "roche-montane") and hence did not provide good 3-dimensional data. Therefore, the orientation data used in the studies of Horne et al. (1988; 1992) may be skewed toward steeply-dipping dykes that intersected the outcrop surface. Horne et al. (1988; 1992) noted that the dykes, unlike the quartz veins and fractures/joints, did not show "clustered" orientations. Rather the dykes had random steeply-dipping orientations (Figure 3.3). However, there were slight "maxima" that corresponded to those of the veins and joints. He interpreted this to reflect the relative timing of the vein formation. Early or co-magmatic dykes were more randomly intruded early in the crystallization sequence while the host rocks were relatively plastic, whereas the latter veins are intruded synchronously with the formation of the brittle joints. In several locations in the batholith, dykes were mostly northwest-oriented, that is parallel to the quartz veins, whereas in other areas the dykes orientations approximated the granite/country rock contacts.



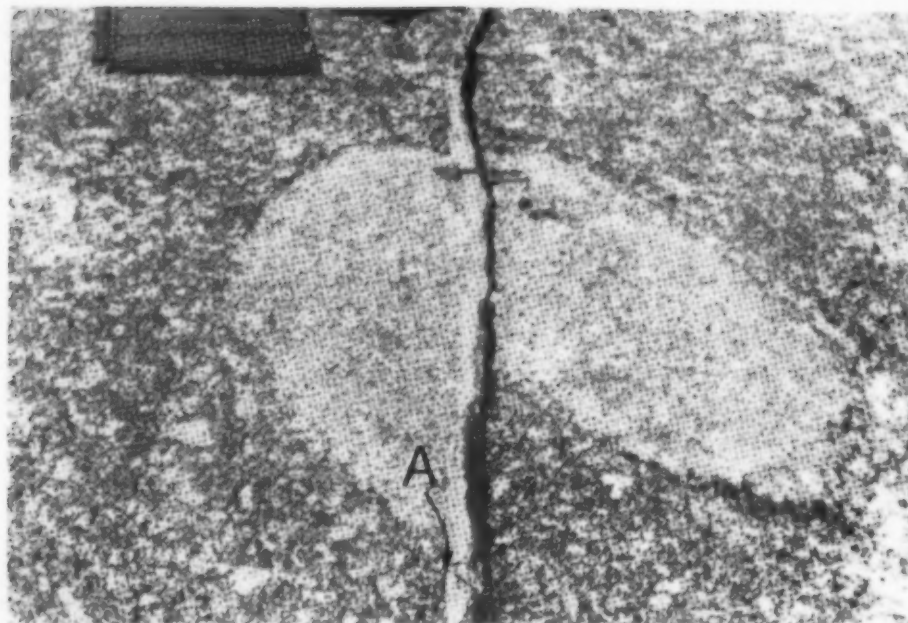


**Plate 3.15** Narrow aplite dyke cross-cutting an igneous xenolith and host biotite monzogranite (pencil and clipboard for scale).

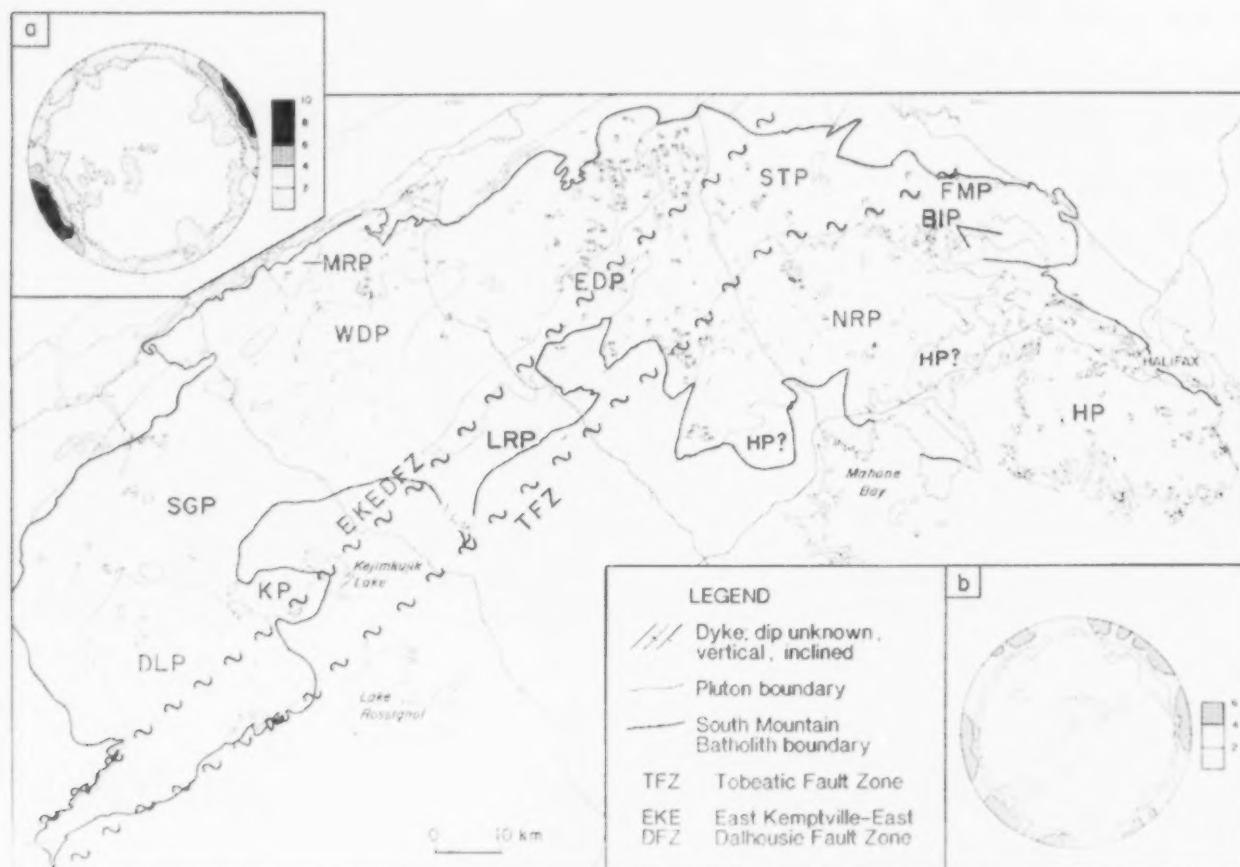


**Figure 3.3** Map showing the distribution and orientation of dykes in the South Mountain Batholith. Poles to dykes have been plotted on stereonet density plots (in 1% area) for the portion of the batholith: a) west and b) east of the Tobeatic Fault Zone (after Horne et al., 1992).

Most pegmatite dykes were noted in the New Ross Pluton and include Morley's Pegmatite, Sefferensville Pegmatite, Long Lake pegmatite, Walker Moly (O'Reilly et al., 1982; Ham and Horne, 1987; Ham, 1990). Several pegmatites have also been reported from numerous isolated locales throughout the batholith, mainly within Stage II plutons (reported on virtually all of the 1:50,000 maps). However, compared to other granitic plutons, in particular in the southern parts of the Meguma Zone such as the Port Mouton and Shelburne plutons, the South Mountain Batholith contains volumetrically very minor pegmatite. The implications of this, in terms of the crystallization of the batholith, will be discussed later.

The wide compositional range for dykes is evident within an outcrop of Sandy Lake biotite monzogranite at the intersection of the #103 highway and St. Margaret's Bay Road near Halifax (Figure 3.4a,b). MacDonald (1993) described a series of aplite, aplite/pegmatite and pegmatite dykes from this outcrop that have varying orientation, from subhorizontal to steeply-dipping. Dyke thicknesses range from 5-10 cm to > 1m. MacDonald (1993) noted a wide range in modal mineralogy in the aplite dykes and aplitic portions of composite dykes from this outcrop. Variations in modal mineralogy for these dykes (Table 3.4) includes 0.08-4.3% biotite, 0.1-3.5% muscovite, 0.2-2.6% cordierite, 0-1.6% garnet in addition to substantial variations in quartz (21.6-37.2%), K-feldspar (21.2-51.1%), calcic plagioclase (5.4-15.1%) and albite (12.7-19.1%). A complete discussion of the mineralogy and geochemistry of these dykes, and the implication for generation of "late-staged" dykes in the batholith, will be presented in following sections.

### 3.5 Xenoliths

Information pertaining to xenoliths that was gathered during geological mapping included approximate abundance, size, shape, grain size, texture, and the presence of porphyroblasts and/or megacrysts. To date this information has not been collated and no systematic petrographic studies of xenoliths have been conducted as part of follow-up studies. Therefore, unless stated otherwise, most of the following section is based upon empirical field observations.

Xenoliths in the batholith can be broadly grouped into six main types that include:

- 1) "fresh" metasedimentary xenoliths (Plate 3.16a), commonly with primary sedimentary features. Pelitic xenoliths (Plate 3.16b) may contain porphyroblasts of andalusite (chiastolite variety) and cordierite; 2) fine-grained equigranular xenoliths frequently exhibiting "gneissic" banding (Plate



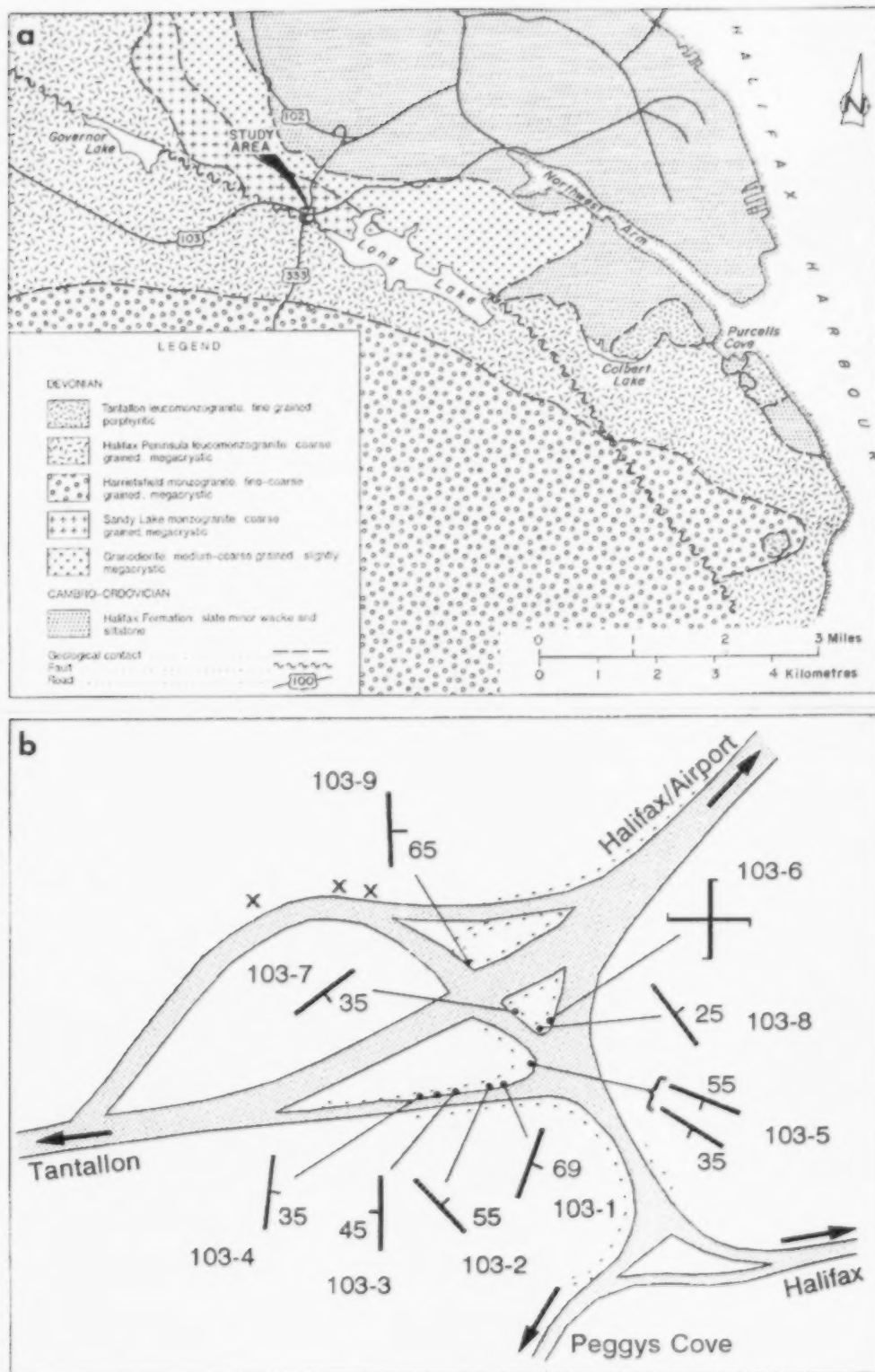


**Figure 3.2** Geology map showing the location of aplite, aplite/pegmatite and pegmatite dykes in an outcrop of Sandy Lake biotite monzogranite from the Halifax Pluton. a) general geology of the northeastern part of the Halifax Pluton; b) detailed location map showing the distribution, sample numbers and orientation of dykes.

Table 3.4. Image analysis - derived modal mineralogy of aplite dykes (1000-2000 points).

|                                 | A1-A | A1-B | A1-B2 | A3   | A4   | A5-A | A5-B | A5-C | A5-D | A8   | A9   |
|---------------------------------|------|------|-------|------|------|------|------|------|------|------|------|
| Quartz                          | 31.7 | 30.6 | 32.4  | 30.0 | 34.4 | 34.0 | 21.6 | 22.2 | 21.8 | 32.5 | 37.2 |
| K-feldspar                      | 35.3 | 34.4 | 32.1  | 37.6 | 23.5 | 21.2 | 50.0 | 51.1 | 53.4 | 27.6 | 30.9 |
| Plagioclase (An <sub>55</sub> ) | 9.2  | 9.6  | 9.9   | 6.4  | 8.6  | 15.1 | 5.4  | 5.5  | 5.4  | 9.0  | 10.8 |
| Albite (An <sub>55</sub> )*     | 14.4 | 12.7 | 14.2  | 15.4 | 17.8 | 16.8 | 17.0 | 15.5 | 14.4 | 19.1 | 13.8 |
| Muscovite**                     | 1.5  | 2.1  | 2.1   | 3.2  | 2.7  | 2.5  | 0.1  | 0.1  | 0.4  | 3.5  | 2.0  |
| Biotite                         | 3.5  | 3.1  | 2.8   | 2.8  | 4.3  | 0.9  | 0.08 | 0.08 | 0.1  | 1.8  | 0.1  |
| Garnet                          | -    | -    | -     | -    | 0.1  | 1.6  | 0.2  | 0.04 | 0.2  | -    | -    |
| Cordierite                      | 0.3  | 0.5  | 0.08  | 0.1  | 0.6  | 0.2  | 0.04 | 0.04 | 0.2  | 0.2  | 0.1  |
| Pinite***                       | 0.3  | 0.1  | 0.2   | 0.1  | 2.0  | 2.1  | 1.0  | 1.1  | 0.9  | 0.6  | 0.1  |
| Chlorite****                    | 0.09 | 0.3  | 0.4   | 0.4  | 0.3  | 0.4  | -    | 0.04 | 0.04 | 0.6  | 0.04 |
| Apatite                         | 0.4  | 0.2  | 0.1   | 0.3  | 0.2  | -    | -    | -    | -    | 0.8  | -    |
| Opaque (oxides)                 | -    | -    | -     | -    | -    | 0.05 | -    | 0.04 | -    | 0.03 | -    |
| Unclassified*****               | 3.2  | 6.5  | 5.8   | 4.7  | 5.4  | 4.8  | 4.4  | 4.1  | 3.5  | 4.4  | 4.8  |

\* Albite - as exsolution lamellae in K-feldspar, rims on zoned plagioclase, and discrete grains

\*\* Muscovite - alteration of K-feldspar, biotite, cordierite and plagioclase

\*\*\* Pinite - alteration of cordierite

\*\*\*\* Chlorite - alteration of cordierite and/or biotite

\*\*\*\*\* Includes analysis at grain boundaries and balsam (i.e. "holes" in slides)

3.16d); 3) fine- to medium-grained xenoliths with abundant medium- to coarse-grained megacrysts of quartz, alkali feldspar and plagioclase (Plate 3.16c). These may also contain metasedimentary xenoliths; 4) medium- to coarse-grained xenoliths with a "ghost-like" appearance (i.e., granitic rocks with a slightly higher biotite content); 5) fine- to medium-grained equigranular leucomonzogranite xenoliths with granitic texture (Plate 3.16c); and 6) granitoid xenoliths from other rock units (Plate 3.16f) of the batholith (e.g. mafic porphyry). Only group #1 can conclusively be assigned to metasedimentary rocks of the Meguma Group. Groups #2 to #4 are tentatively interpreted as partially to extensively assimilated metasedimentary country rocks, in accord with the conclusions of Jamieson (1974). Group #5 has well-developed granitic textures but do not obviously resemble other granitic rock units from the batholith. These xenoliths have low mafic mineral contents and generally are primarily found in biotite-rich monzogranite and granodiorite which were emplaced and crystallized prior to crystallization of Stage II pluton leucomonzogranites. One explanation for this discrepancy is that group #5, and in fact some of groups #2 to #4 xenoliths, may be high-grade metamorphic rocks from deeper crustal levels, possibly from the zone of partial melting. However, detailed petrographic investigations are

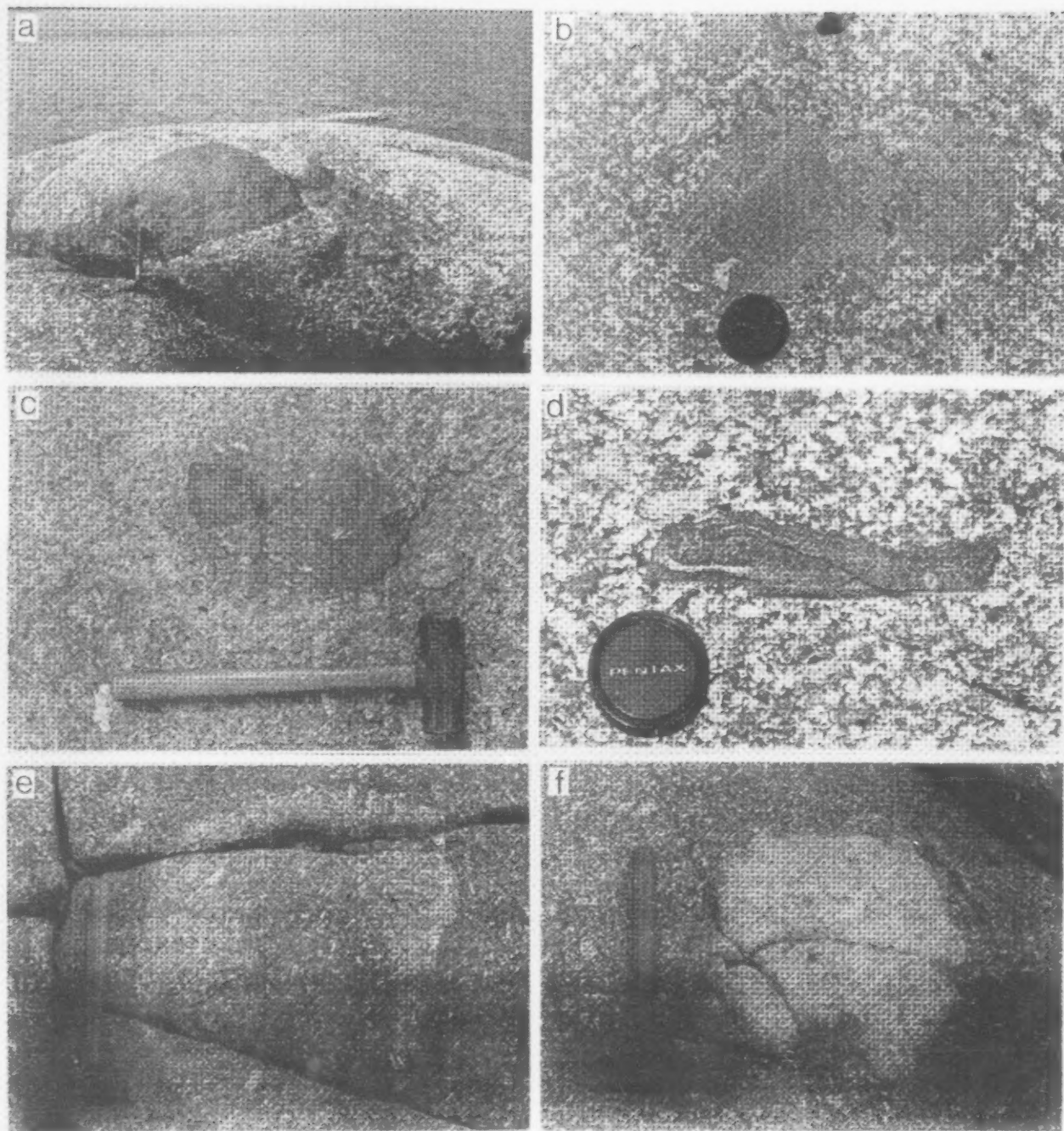


Plate 3.16(a to e) Typical variations in xenoliths in the South Mountain Batholith (see text for description).

required to successfully resolve this issue. Group #6 xenoliths can generally be assigned to other rock units and, unlike group #5, follow the general crystallization sequence of the batholith. That is, *xenoliths are more mafic than their host rocks.*

Perhaps the most important observation about xenoliths pertains to the distribution. The abundance of xenoliths in any rock unit is directly proportional to the modal proportions of biotite±cordierite. The highest xenolith abundance is the least evolved, biotite-rich, mafic porphyry and granodiorite units. The abundance of xenoliths decreases in muscovite-biotite monzogranite and only rare xenoliths were noted in some portions of coarse-grained leucomonzogranite. Xenoliths are rare to absent in fine-grained leucomonzogranite and leucogranite, even when in direct contact with country rocks. In general the proportion of xenoliths within map units in granodiorite and monzogranite units is evenly distributed with the exception of several areas close to country rock contacts, such as at Palmer Lake (MacDonald and Ham, 1992) and Mount Uniacke (Jamieson, 1974). Also, a few xenolith "dykes" were noted in granodiorite and biotite monzogranite units in the batholith. The origin of these "dykes" is unclear.

To date, the only documented "exotic" xenolith consists of a single enclave that was intersected in drill core in the Big Indian Lake Pluton (Corey and Chatterjee, 1992). This xenolith contains garnet + clinopyroxene + plagioclase + titanite and was noted to be 'remarkably similar' to lower crustal granulite xenoliths with the same essential mineralogy that were reported in the Tangier lamprhyre dyke (Fig. 1.2; Chatterjee and Giles, 1988). The Big Indian Lake 'exotic' xenolith is tentatively interpreted as a refractory inclusion from the zone of partial melting and/or a high-grade metamorphic rock that was incorporated into the Big Indian Lake Pluton during ascent to the present emplacement level (M.C. Corey, pers. comm., 1993).



## Chapter 4

### PETROGRAPHY

#### 4.1 General Petrography of Major Rock Types

All granitic rocks of the batholith contain essential quartz, alkali feldspar and plagioclase (QAP). A contoured density plot of 452 representative QAP determinations from the entire batholith is given in Figure 4.1a. The bulk of the batholith is composed of monzogranite and, to a lesser extent, granodiorite with minor tonalite and syenogranite. It should be noted that Streckeisen (1976; Fig. 4.1b) grouped plagioclase of  $An_{<5}$  composition with alkali feldspar. Detailed petrographic studies (Smith et al., 1986; MacDonald and Horne, 1988; MacDonald et al., 1992) report albitic plagioclase in leucomonzogranite rocks of the batholith. In fact, recent studies of leucogranitic rocks by Kontak (1990), MacDonald and Clarke (1991) and Clarke et al. (1993) noted the anorthite content of plagioclase in most leucogranite bodies is  $< An_5$ . Grouping this plagioclase with alkali feldspar would shift the compositions toward the alkali feldspar-quartz join of the QAP diagram, that is, into the syenogranite and alkali feldspar fields. The determination of the exact amount of albite with  $An_{<5}$  would require extensive petrographic/microprobe analysis. Therefore, for the purpose of developing a field method for rock classification (see discussion in Chapter 2), all plagioclase compositions have been grouped together.

Modal plots for the six major rock types for the entire batholith are given in Figs. 4.1c-e. The wide degree of scatter within each rock type can be attributed to compositional variation, textural heterogeneities and varying degrees of metasomatism (e.g. K-feldspathization, albitization) both within, and between, the various map units. In addition, counting error and operator bias presumably contribute to the degree of scatter, albeit of an unknown amount. It is apparent from the individual plots in Figure 4.1 that A/P increases from biotite granodiorite to fine-grained leucomonzogranite and leucogranite.

A summary of the overall textural and petrographic characteristics of the six main rock types is given in Table 3.1 and schematically depicted in Figure 4.2. Consistent textural characteristics were noted in the granitic rocks throughout the batholith. For example, biotite

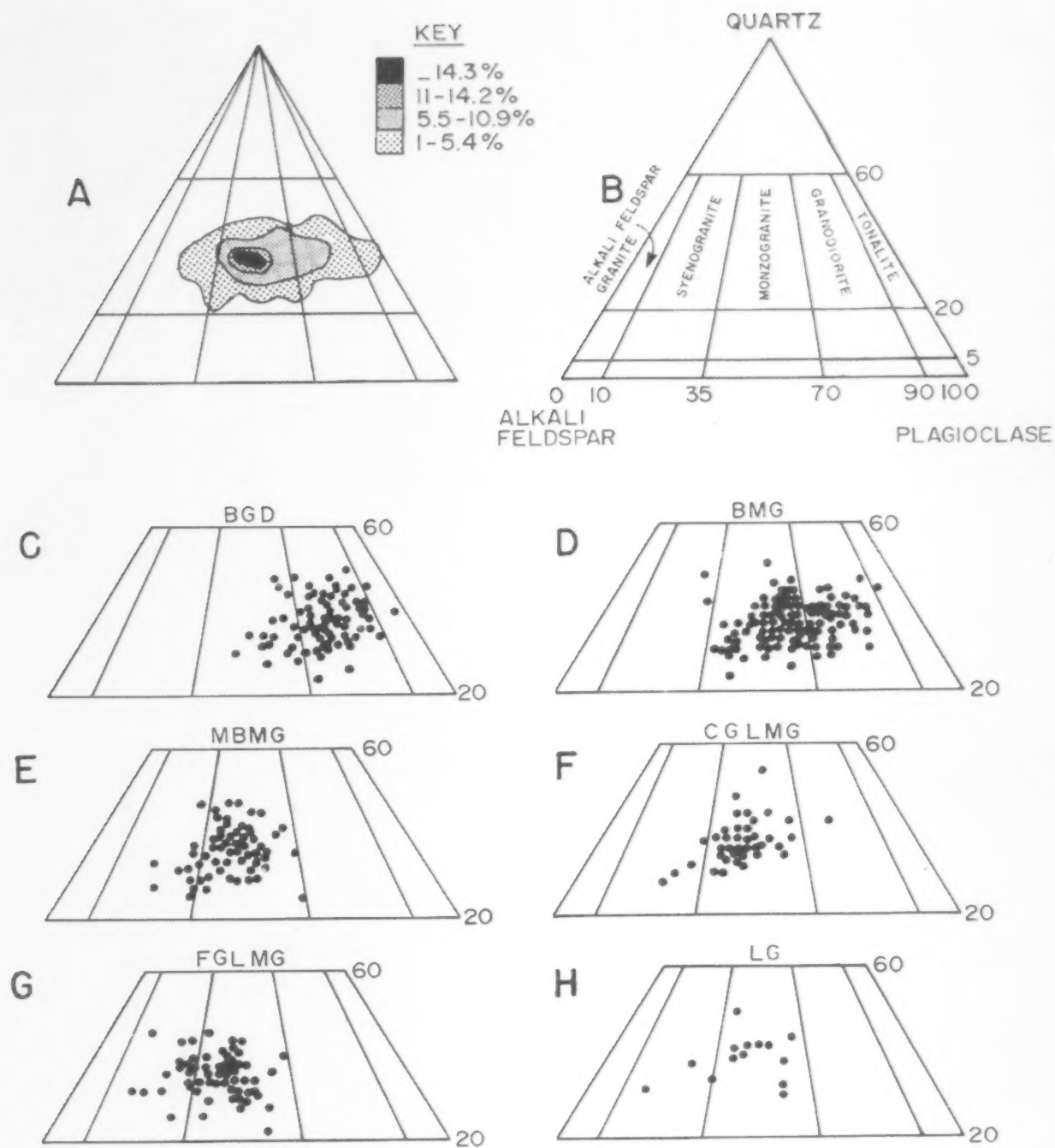


**Figure 4.1** (a) Contoured QAP plot of 452 representative samples from the batholith indicating a predominantly monzogranitic-granodioritic composition; (b) fields after Streckeisen (1976); QAP plots of representative samples from (c) biotite granodiorite (BGD); (d) biotite monzogranite (BMG); (e) muscovite-biotite monzogranite (MBMG); (f) coarse-grained leucomonzogranite (CGLMG); (g) fine-grained leucomonzogranite (FGLMG); (h) leucogranite (LG).

granodiorite, biotite monzogranite, muscovite-biotite monzogranite and coarse-grained leucomonzogranite units are mostly medium- to coarse-grained with megacrystic or seriate textures, although, as previously noted in Chapter 3, fine- to coarse-grained porphyritic or equigranular textures are locally developed in these rock types. In contrast, fine-grained leucomonzogranite and leucogranite units are mostly fine- to medium-grained with porphyritic or equigranular textures, although fine- to coarse-grained aplitic, pegmatitic, seriate and megacrystic textures are developed in some units (e.g. Tantallon Leucomonzogranite, MacDonald and Home, 1987; Murphy Lake Leucogranite, MacDonald and Ham, 1992).

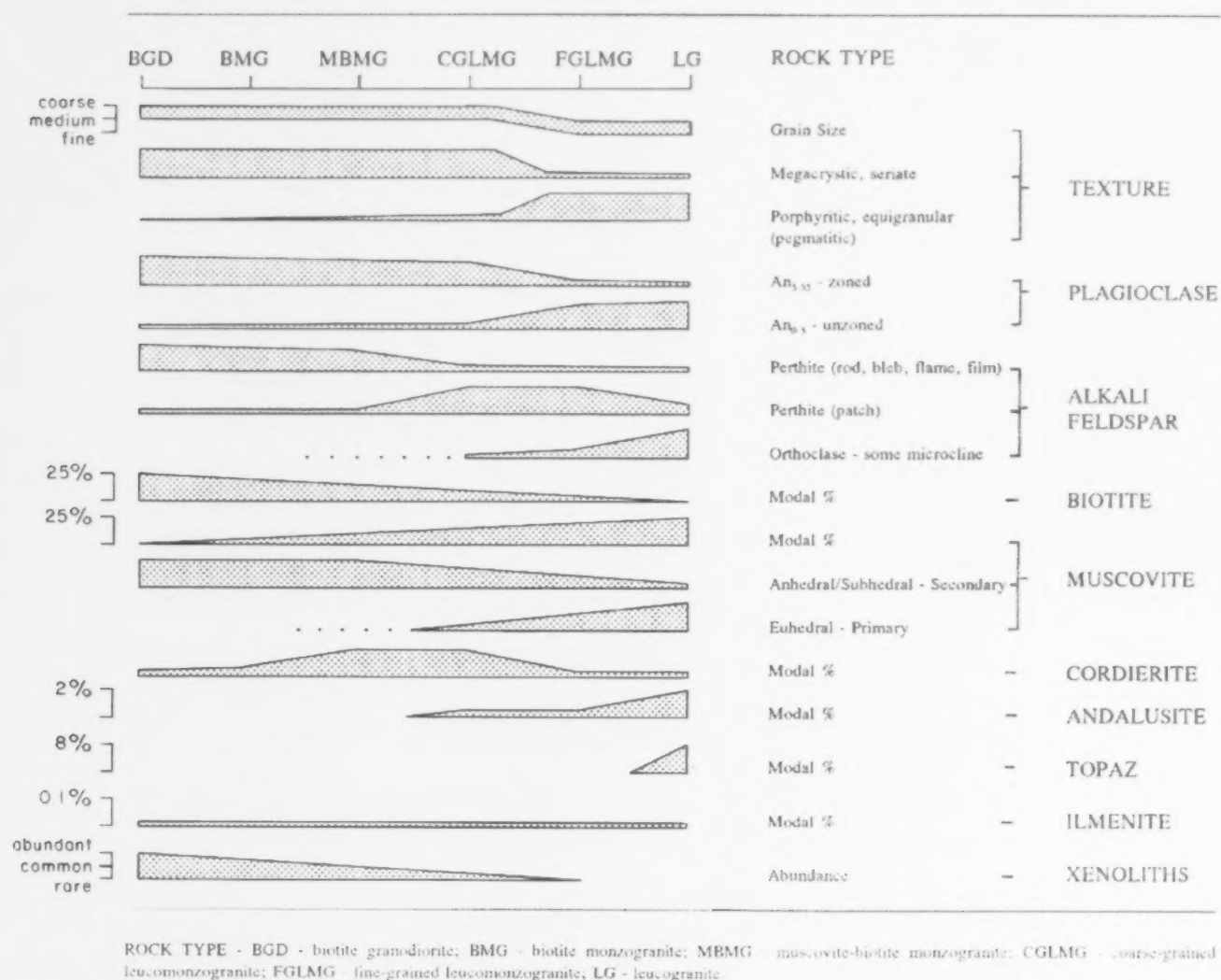


**Figure 4.2** Summary of the main petrological features of the South Mountain Batholith showing the systematic changes from least evolved biotite granodiorite to most evolved leucogranite.

Systematic petrographic variations noted throughout the batholith define a sequence from least evolved granodiorite to most evolved leucogranite. These variations include: (1) **biotite** (Plate 4.1a) with inclusions of apatite, zircon (Plate 4.1b), monazite, ilmenite  $\pm$  xenotime  $\pm$  epidote  $\pm$  titanite, decreases from  $>25\%$  in some granodiorite units to absent or trace amounts in several leucogranite units; (2) **muscovite** increases from trace amounts in most granodiorite units to  $>25\%$  in several metasomatized leucogranite units. Muscovite generally occurs as anhedral grains replacing feldspar (Plate 4.1c) in granodiorite units to euhedral to subhedral grains (primary magmatic?; Plate 4.1d) in several fine-grained leucomonzogranite and leucogranite units; (3) **cordierite** (Plate 4.1e) and pinitite/muscovite pseudomorphs (Plate 4.1f) occur in minor amounts in most units, but is most abundant in monzogranite and coarse-grained leucomonzogranite units where it may exceed 5% of the mode; (4) **alkali feldspar** is perthite in the majority of the batholith with rod, bleb, flame and film type exsolution (Plate 4.1g) dominant in granodioritic and monzogranitic rocks while patch type perthite (Plate 4.1h) is more common in leucomonzogranite units. In most leucogranite units the alkali feldspar rarely has a perthitic texture; (5) **plagioclase** ( $An_{5-35}$ ) is typically zoned (normal and oscillatory types; Plate 4.1i) in granodiorite and biotite monzogranite units, zoned and unzoned in leucomonzogranite units and unzoned ( $An_{5-5}$ ; Plate 4.1j) in most leucogranite units; (6) **andalusite** (Plate 4.1k), with characteristic alteration to muscovite, is most abundant in fine-grained leucomonzogranite and leucogranite units; (7) subhedral to euhedral (primary magmatic?) **topaz** (Plate 4.1l) is restricted to leucogranite rocks such as at East Kemptville where it may constitute up to 8% of the mode (Kontak, 1990; Ham and MacDonald, 1991).

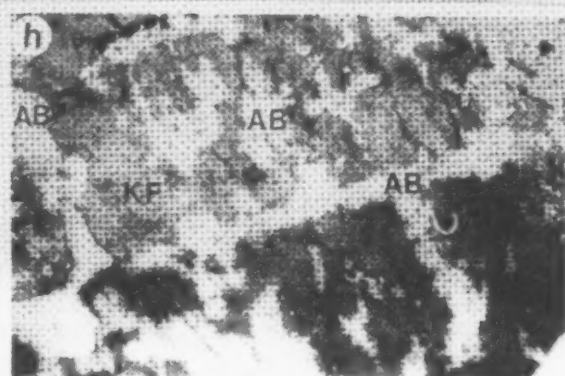
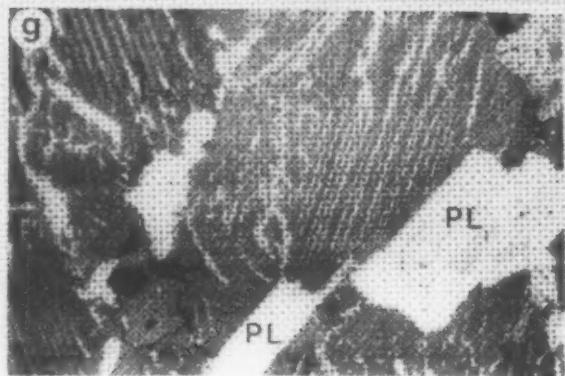
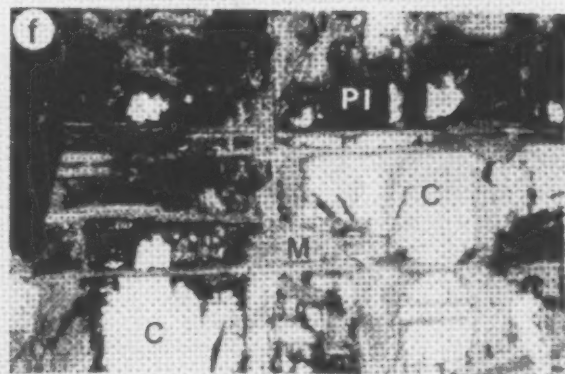
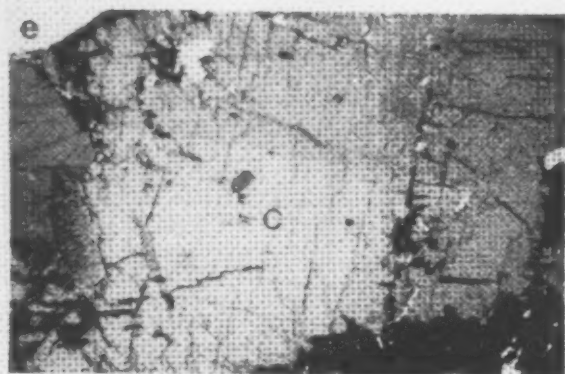
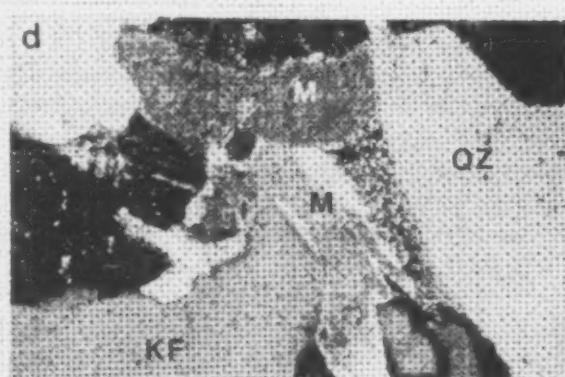
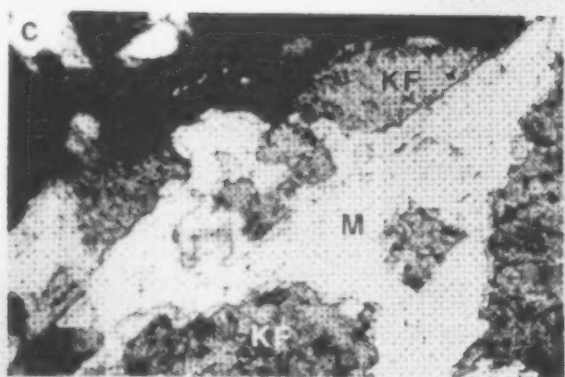
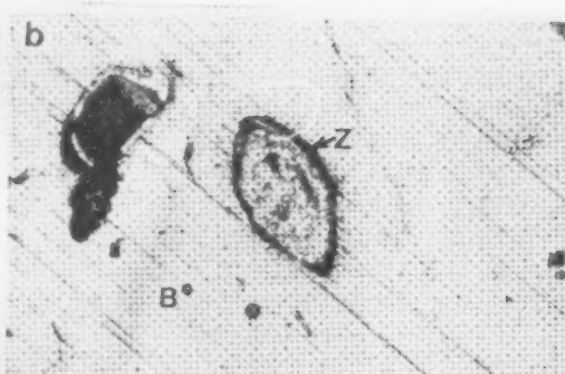
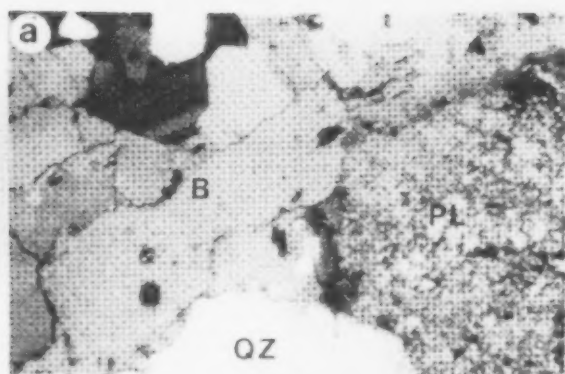
## 4.2 Mineralogy

The following sections summarize the mode(s) of occurrence for most of the major, minor and accessory mineral phases in the batholith. In addition, key references are cited for interested readers.

### 4.2.1 Quartz

Quartz is a ubiquitous mineral phase in virtually all rocks of the batholith where it occurs as an anhedral to subhedral groundmass, or intergranular, constituent (Plate 4.2a). It commonly forms subhedral "quartz eyes" in megacrystic rocks and subhedral to euhedral phenocrysts in many porphyritic units (Plate 4.2b). Quartz is commonly present as subhedral to euhedral





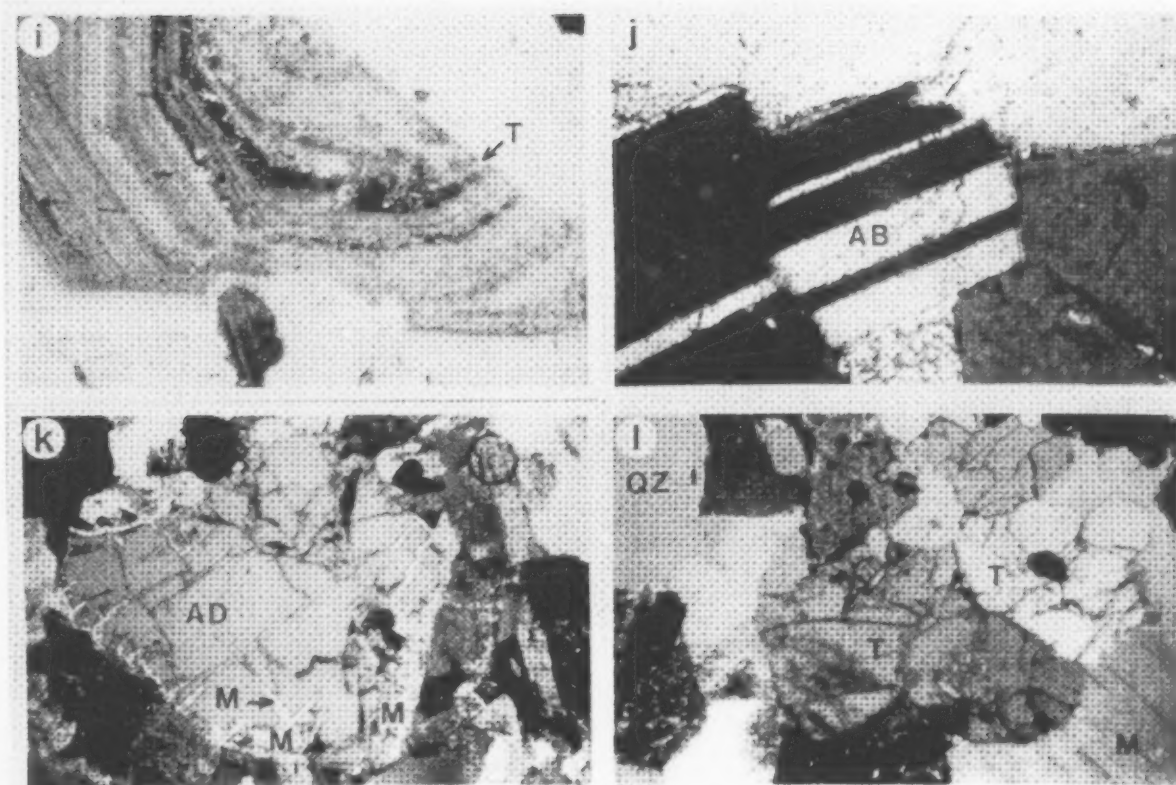
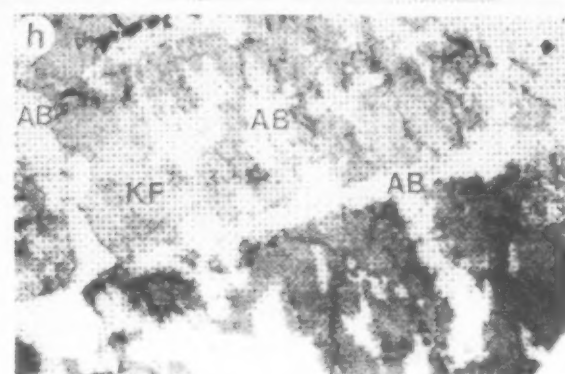
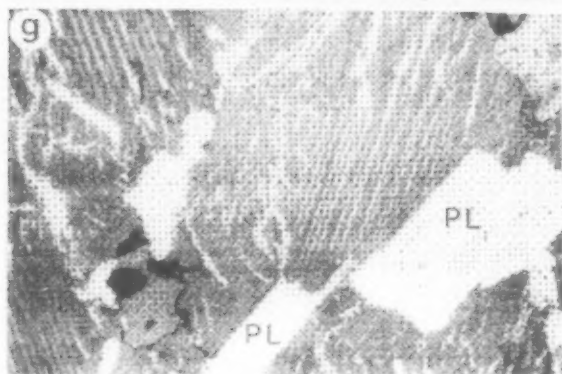
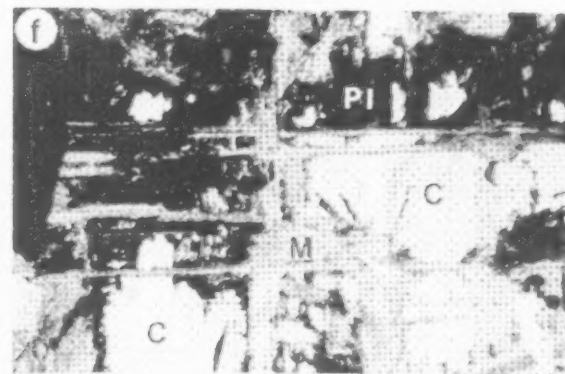
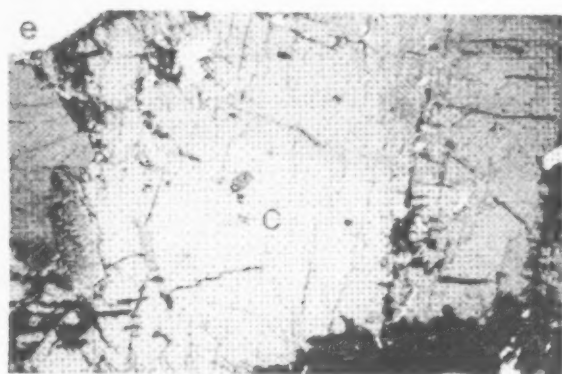
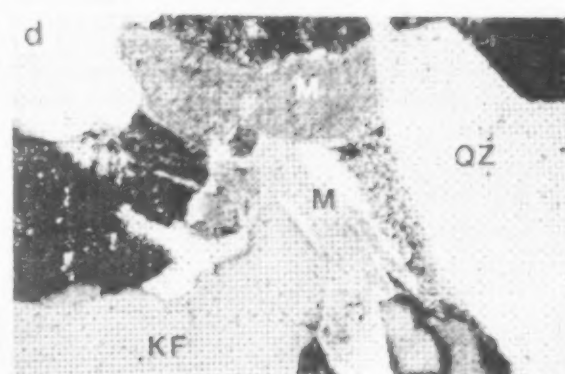
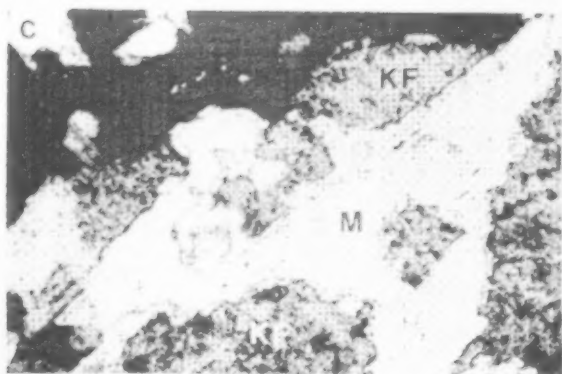
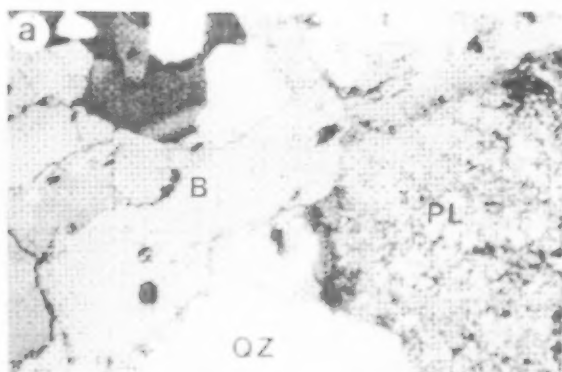


**Plate 4.1** Photomicrographs illustrating typical mineralogical and textural feature of the plutons of the South Mountain Batholith; Length of photographs is 1 mm in all photos except 0.4 mm in b and j; all are in crossed polarized light. (a) biotite (B) with inclusions of zircon and/or monazite with pleochroic halos, sericitized plagioclase (PL) and quartz (QZ) in megacrystic granodiorite; (b) zircon (Z) inclusion in biotite (B) in biotite monzogranite; (c) secondary muscovite (M) replacing alkali feldspar (KF) in coarse-grained leucomonzogranite; (d) euhedral to subhedral (primary?) muscovite (M) in leucogranite; (e) pristine cordierite crystal (C), showing prominent twin plane, in biotite monzogranite; (f) typical altered cordierite crystal (C) in coarse-grained leucomonzogranite with secondary muscovite developed along prominent crystallographic directions (010) and pseudomorphic replacement by pinite (PI); (g) large alkali feldspar megacryst in biotite monzogranite displaying rod, bleb, flame and film type perthitic exsolution and euhedral inclusions of plagioclase (PL); (h) alkali feldspar megacryst (KF) in coarse-grained leucomonzogranite with patch perthite exsolution of albite (AB); (i) plagioclase grain in biotite granodiorite displaying well developed oscillatory zoning and simple twin plane (T); (j) euhedral albite crystal (AB) in leucogranite; (k) andalusite grain (AD) with characteristic alteration to muscovite (M) in fine-grained leucomonzogranite; (l) cluster of topaz crystals (T) and adjoining muscovite (M) in leucogranite.

inclusions in plagioclase (Plate 4.2c) and alkali feldspar, routinely defining growth planes within feldspar megacrysts. Quartz is perhaps the most characteristic mineral in hydrothermally altered zones (Plate 4.2d) associated with polymetallic Sn-W mineralization. Large modal amounts of quartz in these zones may either reflect the presence of  $\text{SiO}_2$ -rich hydrothermal fluids or the



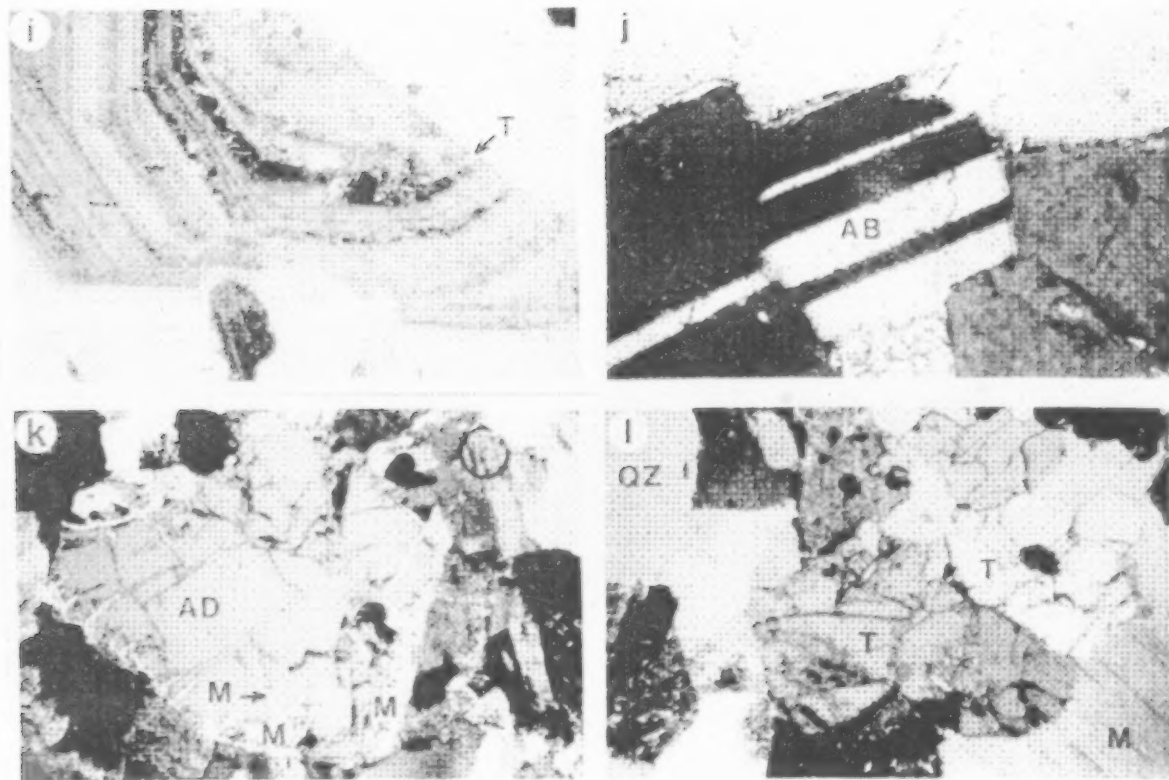


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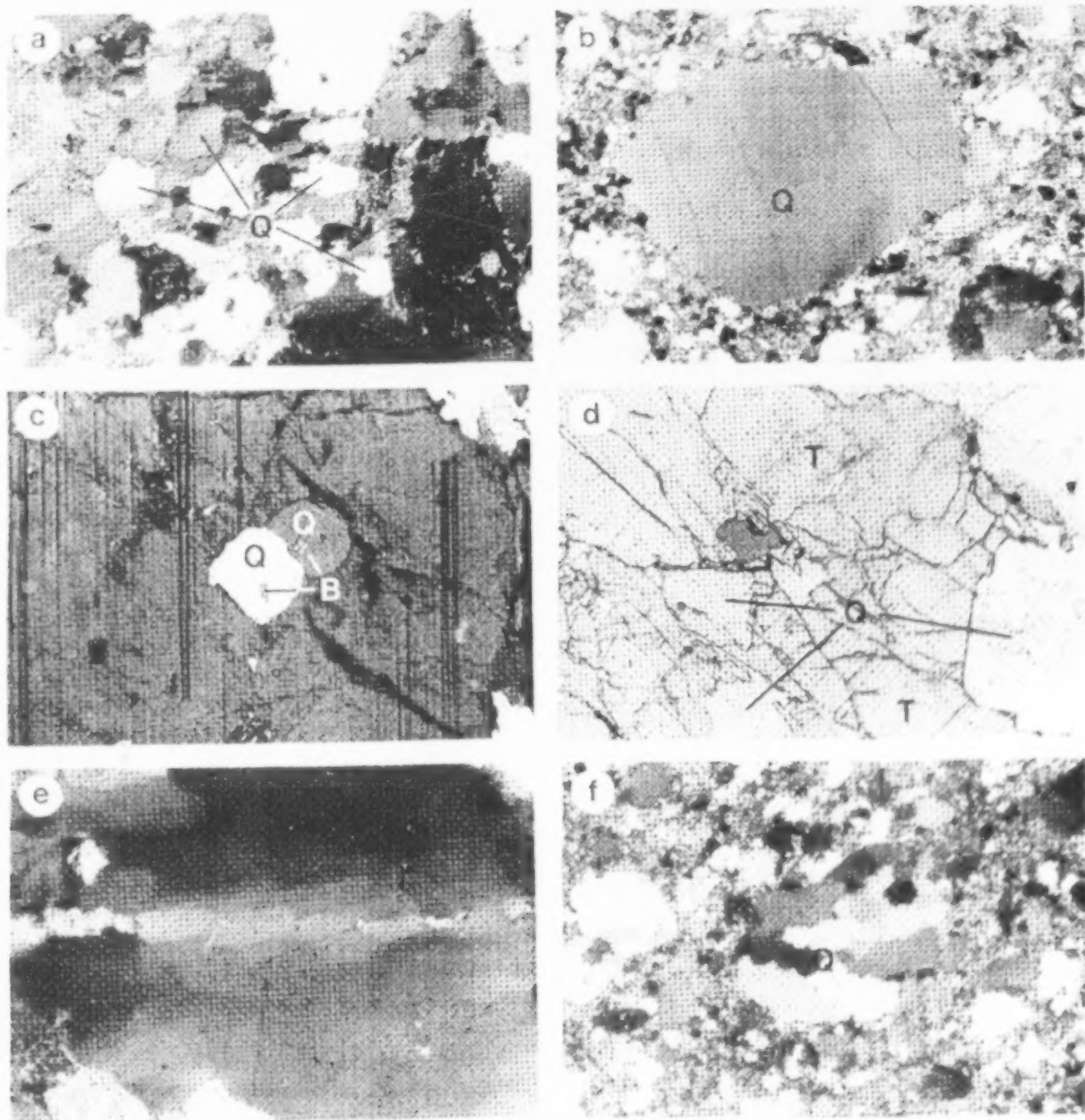


**Plate 4.2** Photomicrographs illustrating typical petrographic features of quartz (Q) in the South Mountain Batholith; Length of photographs is 1 mm in all photos except 0.4 mm in c and e; all are in crossed polarized light. a) anhedra and subhedra quartz as a groundmass constituent in muscovite-biotite monzogranite; b) quartz phenocryst in porphyritic fine grained leucomonzogranite; c) quartz inclusions, containing euhedral biotite inclusions (B), in plagioclase grain with well-developed polysynthetic twinning; d) quartz-tourmaline (T) intergrowth in greisen zone from Inglisville (MacDonald and Ham, 1994b); e) typical undulose extinction in quartz grain in muscovite-biotite monzogranite; f) undulose extinction and subgrain development in quartz phenocryst in muscovite leucogranite.

removal of other chemical components (e.g. alkalis) during hydrothermal alteration. The only rock type in the entire batholith that is devoid of quartz is episyenite (i.e. desilicified) which occurs as alteration zones in all rock types, often associated with U mineralization (see Chapter 9 for discussion).



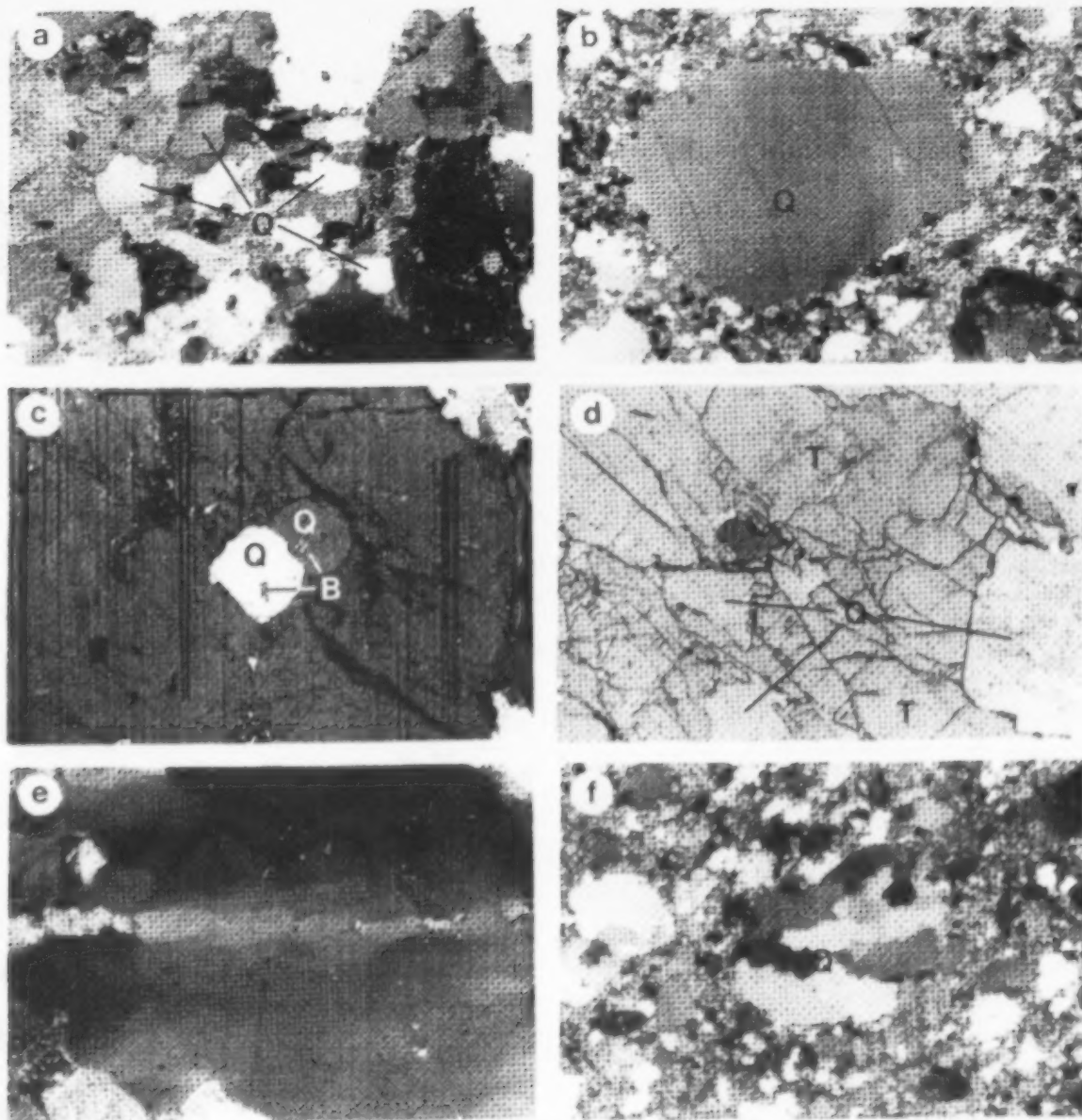


**Plate 4.2** Photomicrographs illustrating typical petrographic features of quartz (Q) in the South Mountain Batholith: Length of photographs is 1 mm in all photos except 0.4 mm in c and e; all are in crossed polarized light. a) anhedronal and subhedronal quartz as a groundmass constituent in muscovite-biotite monzogranite; b) quartz phenocryst in porphyritic fine grained leucomonzogranite; c) quartz inclusions, containing euhedral biotite inclusions (B), in plagioclase grain with well-developed polysynthetic twinning; d) quartz-tourmaline (T) intergrowth in greisen zone from Inglisville (MacDonald and Ham, 1994b); e) typical undulose extinction in quartz grain in muscovite-biotite monzogranite; f) undulose extinction and subgrain development in quartz phenocryst in muscovite leucogranite.

removal of other chemical components (e.g. alkalis) during hydrothermal alteration. The only rock type in the entire batholith that is devoid of quartz is episyenite (i.e. desilicified) which occurs as alteration zones in all rock types, often associated with U mineralization (see Chapter 9 for discussion).

Quartz displays variable amounts of undulose extinction (Plate 4.2e) in most units throughout the batholith. Local areas may also show variable development of granoblastic textures with equidimensional grains and well sutured boundaries (Plate 4.2f). These textural features in quartz indicate the batholith was subject to structural stress following crystallization, which will be discussed further in Chapter 6.

#### 4.2.2 Plagioclase

Plagioclase is a major constituent in all rocks of the batholith. It occurs as anhedral, subhedral (Plate 4.3a) and euhedral groundmass grains in all rocks and as megacrysts in most megacrystic rocks and phenocrysts (Plate 4.3b) in many porphyritic rocks. Plagioclase commonly occurs as euhedral inclusions in alkali feldspar and to a lesser extent in quartz and may contain inclusions of biotite, quartz (Plate 4.3c) and, less frequently, garnet or cordierite.

As noted above, plagioclase exhibits systematic textural and compositional changes with degree of differentiation of host rock. MacDonald and Horne (1988) presented a summary of these variations for plagioclase in the Halifax Pluton. MacDonald et al. (1992) concluded that plagioclase in the rest of the batholith showed similar textural and compositional features as in the Halifax Pluton. In most **biotite granodiorite** and **biotite monzogranite** units of the batholith plagioclase is chiefly zoned with normal, oscillatory and to a lesser degree patchy zoning. Unzoned plagioclase is mainly absent with the exception of some albitic rims on zoned plagioclase grains. Myrmekitic intergrowths of albite and quartz (Plate 4.3d) or unzoned albite (Plate 4.3e) may form rims on variably zoned plagioclase grains in these rocks. Plagioclase is predominantly unaltered in these rocks with minor amounts of sericitic alteration, primarily in Ca-rich cores. MacDonald and Horne (1988) reported plagioclase compositions ranging from  $An_{15-33}$  in biotite granodiorite and  $An_{11-36}$  in biotite monzogranite from the Halifax Pluton. In **muscovite-biotite monzogranite** and **coarse-grained leucomonzogranite** units plagioclase occurs as a variety of weakly to moderately zoned grains with normal, patchy and to a lesser degree oscillatory zoned and unzoned crystal. Myrmekite rims are rare to absent and alteration consists of weak to intense replacement by sericite. MacDonald and Horne (1988) reported plagioclase compositions in these rocks ranging from  $An_{2-30}$ . Plagioclase in **fine-grained leucomonzogranite** is mainly unzoned or displays weak normal zoning. Myrmekite rims are absent in these rocks and alteration to secondary sericite and/or muscovite is moderate to intensely developed.

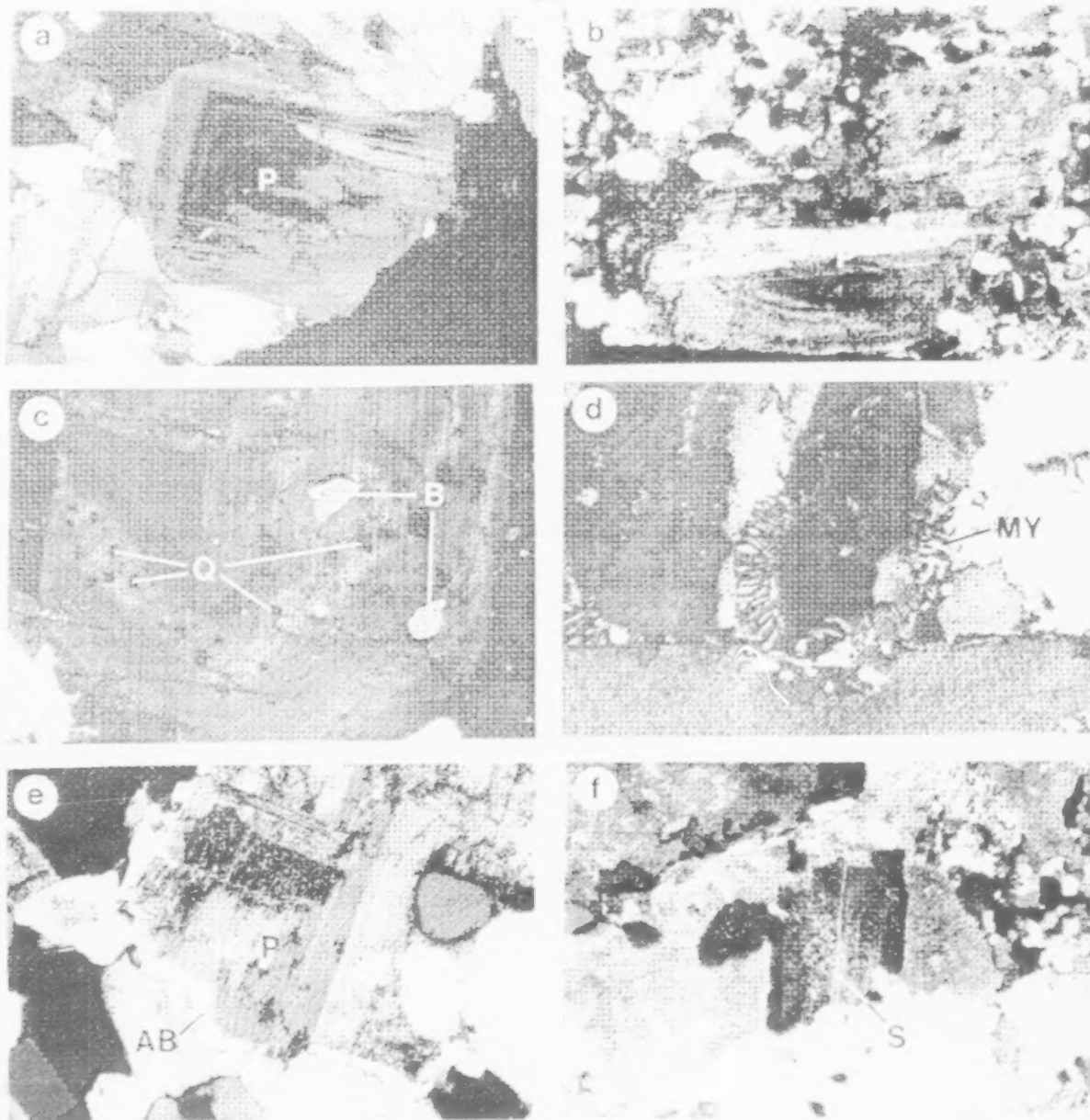


Plate 4.3 Photomicrographs illustrating typical petrographic features of plagioclase (P) in the South Mountain Batholith: Length of photographs is 1 mm in all photos except 0.4 mm in d and e; all are in crossed polarized light. a) subhedral, zoned plagioclase grain in biotite granodiorite; b) plagioclase phenocrysts in fine-grained leucomonzogranite; c) quartz (Q) and biotite (B) inclusions in zoned plagioclase in biotite monzogranite; d) myrmekitic intergrowths (MY) of albite and quartz rimming plagioclase in biotite granodiorite; e) zoned albite (AB) rim on zoned plagioclase grain in coarse-grained leucomonzogranite; f) sericitized (S) albite in monzogranite.

MacDonald and Hearn (1988) reported plagioclase compositions of fine-grained leucomonzogranite rocks that ranged from  $An_{52}$ ; however, they analysed several phenocrysts

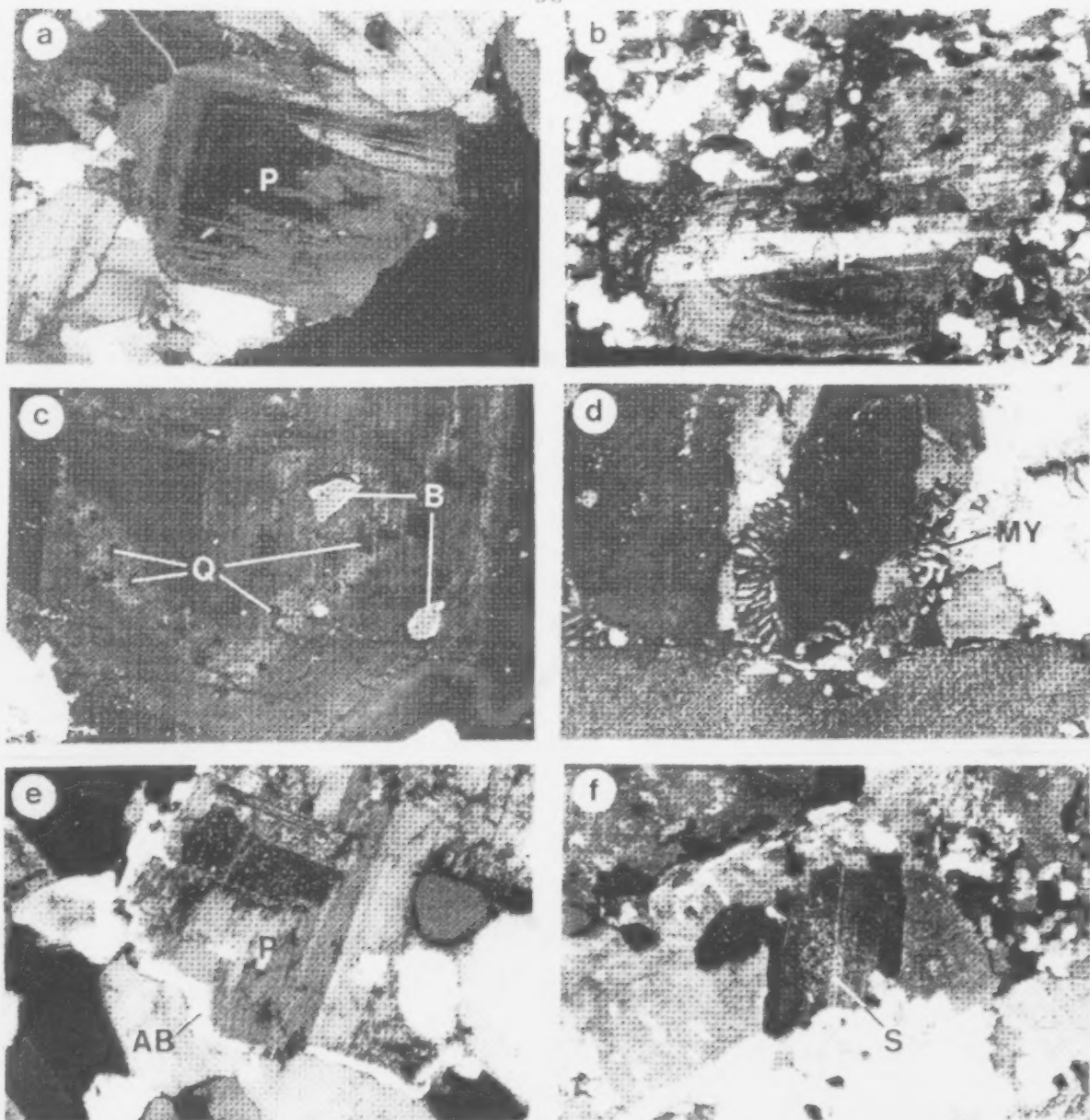


**Plate 4.3** Photomicrographs illustrating typical petrographic features of plagioclase (P) in the South Mountain Batholith; Length of photographs is 1 mm in all photos except 0.4 mm in d and e; all are in crossed polarized light. a) subhedral, zoned plagioclase grain in biotite granodiorite; b) plagioclase phenocrysts in fine-grained leucomonzogranite; c) quartz (Q) and biotite (B) inclusions in zoned plagioclase in biotite monzogranite; d) myrmekitic intergrowths (MY) of albite and quartz rimming plagioclase in biotite granodiorite; e) unzoned albite (AB) rim on zoned plagioclase grain in coarse-grained leucomonzogranite; f) sericitized (S) albite in muscovite leucogranite.

MacDonald and Horne (1988) reported plagioclase compositions in most fine-grained leucomonzogranite rocks that ranged from  $An_{45}$ , however, they analysed several phenocrysts



with compositions of  $An_{15-34}$ . These compositions were in sharp contrast to the albite-oligoclase in the groundmass from the same samples. It is possible that these grains represented crystals that formed in a less evolved (granodiorite?) melt but remained in the residual (i.e. leucomonzogranite) melt. Plagioclase in **leucogranite** is predominantly unzoned, although some weak normal zoning was noted in several leucogranite bodies in the New Ross area and in the Walsh Brook leucogranite near the Big Indian Lake Pluton (Clarke et al., 1993). Plagioclase in some leucogranite bodies is unaltered whereas in others it is moderately to extensively sericitized (Plate 4.3f). Plagioclase compositions in most leucogranite bodies is primarily albitic with  $An_{<5}$  (Kontak, 1990; MacDonald et al., 1992) although some bodies have more calcic compositions with  $An_{1-14}$  (e.g. Walsh Brook and Murphy Lake leucogranites; Clarke et al., 1993).

Albitic plagioclase ( $An_{<5}$ ) is a common mineral phase in many hydrothermally altered zones (mineralized and barren) throughout the batholith. In fact, albitization of host rocks and the occurrence of albitites (Chatterjee and Strong, 1984a) are the dominant styles of alteration in many polymetallic greisen-style mineral occurrences (e.g. Upper New Cornwall; Corey, 1983). The presence of albite in hydrothermally altered zones may be a mineralogical expression of high Na concentration in some hydrothermal fluids which will be further discussed in Chapter 9.

#### 4.2.3 Alkali feldspar

Alkali feldspar is a common mineral constituent in all rock of the batholith. It occurs as anhedral, subhedral and euhedral groundmass grains in all rocks and as megacrysts in many megacrystic rocks and phenocrysts in many porphyritic rocks. Alkali feldspar commonly contains subhedral to euhedral inclusions of plagioclase (Plate 4.4a) and biotite and to a lesser degree anhedral quartz grains which may define growth planes in larger grains and megacrysts.

MacDonald and Horne (1988) noted systematic petrographic variations in alkali feldspar with degree of differentiation of host rocks in the Halifax Pluton. MacDonald et al. (1992) noted similar variations in alkali feldspar textures for the entire South Mountain Batholith. The following section summarizes these features. Alkali feldspar in **biotite granodiorite** and **biotite monzogranite** is perthitic with rod, bleb, flame and film type exsolution lamellae (Plate 4.4b). Most grains are fresh or only weakly altered to sericite. MacDonald and Horne (1988) noted weak development of microcline (Plate 4.4c) in alkali feldspar from samples of biotite monzogranite

in the Halifax Pluton. Alkali feldspar in **muscovite-biotite monzogranite** and **coarse-grained leucomonzogranite** generally occurs as sub-equal proportions of perthite with rod-, bead-, bleb-, string- and film-type exsolution lamellae and patch-type perthite (Plate 4.4d). Richardson (1988) presented a summary of textural variations in alkali feldspar from coarse-grained leucomonzogranite from the Davis Lake Pluton. She concluded that bleb-, string- and film-type exsolution textures represented exsolution whereas variably-developed "patch" and "chessboard" (Plate 4.4e) type textures represented replacement and/or replacement-modified exsolution features. Similar alkali feldspar textures in the rest of the batholith are interpreted as representing the same processes as proposed by Richardson (1988).

Kontak and Strong (1988), Kontak (1988) and Kontak et al. (1991) reported major, trace and rare earth element analyses for alkali feldspar separates from a suite of rock samples representing the complete compositional range of the batholith. These workers noted that the composition of alkali feldspar (e.g.  $\sum \text{REE}$ ,  $\text{Eu}/\text{Eu}^*$ , Rb, Sr, Ba) reflected the compositions of their respective host rocks and subsequently were good indicators of degree of fractionation. Concentrations of  $\text{P}_2\text{O}_5$  increased from 0.1 to  $>1.0$  wt % from granodiorite to leucogranite. Kontak et al. (1991) concluded that P was structurally bound in both the K- and Na-components of alkali feldspar structure. Logothetis (1985) reported secondary grains of apatite in K-spar from the New Ross Pluton that he interpreted as forming from liberation of P from the K-spar structure by late-magmatic (i.e. deuteric) alteration. Kontak et al. (1991) concluded that much of the high levels of  $\text{P}_2\text{O}_5$  in leucomonzogranite and leucogranite rocks ( $>1$  wt %) resided in the K-feldspar structure as opposed to primary magmatic P-bearing phases (e.g. apatite, monazite, xenotime).

Alkali feldspar is a common constituent in many leucogranite and pegmatite dykes and minor intrusives where it may show graphic intergrowths with quartz (plate 4.4f). It may also be present in hydrothermal alteration zones such as the intensely K-feldspathized zones associated with Mo-bearing polymetallic greisens at the Long Lake occurrence (O'Reilly et al., 1982) and several other polymetallic occurrences in the central part of the batholith (Logothetis, 1985). The association between hydrothermal alteration and mineralization will be discussed further in Chapter 9.

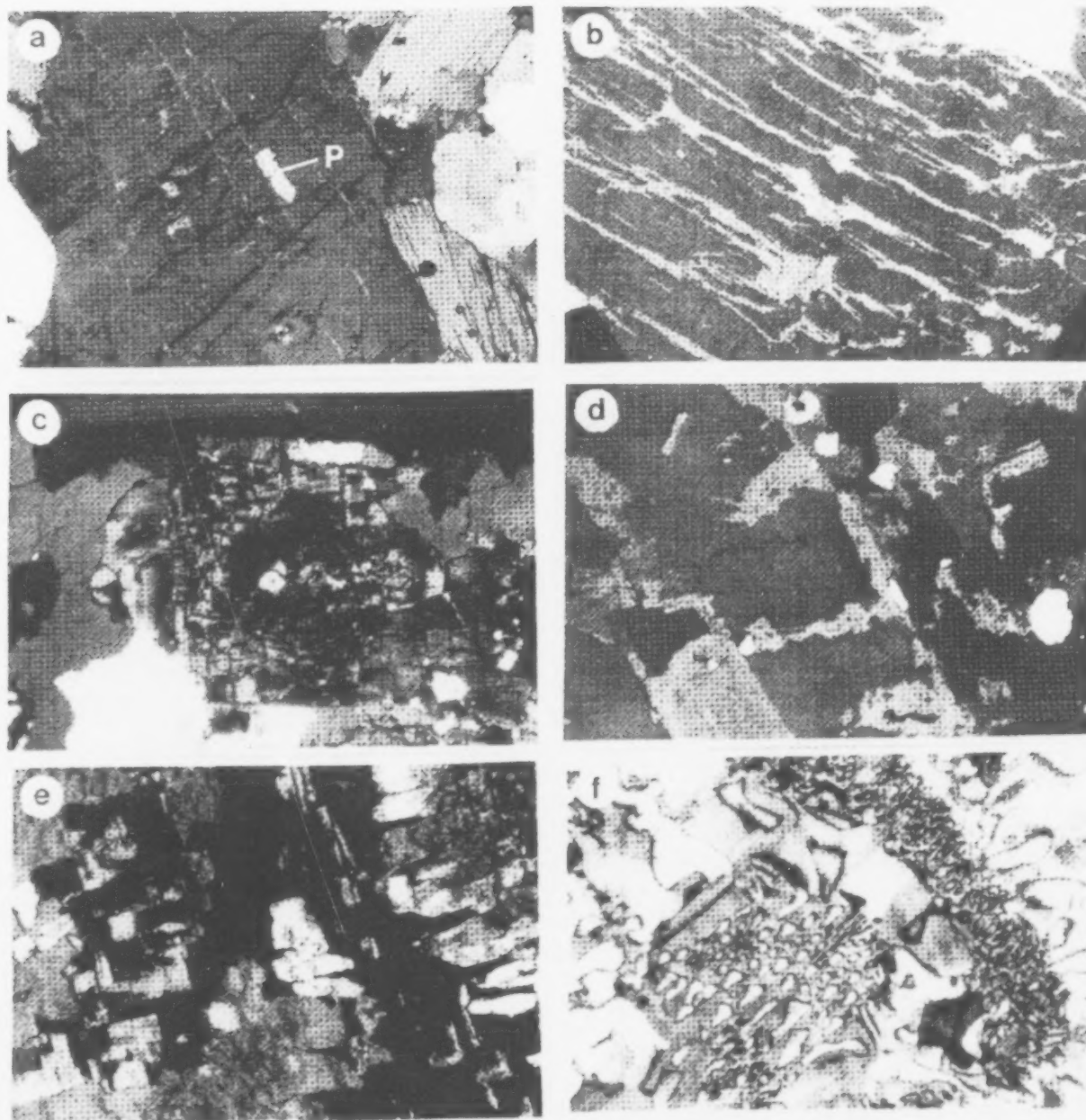


Plate 4.4 Photomicrographs illustrating typical petrographic features of alkali feldspar in the South Mountain Batholith; Length of photographs is 0.4 mm in all photos except 1 mm in b and c; all are in crossed polarized light. a) euhedral plagioclase inclusion (P) in alkali feldspar biotite monzogranite; b) bleb-, string- and film-type exsolution textures in alkali feldspar in biotite monzogranite; c) microcline grain in biotite monzogranite; d) patch-type replacement perthite in coarse-grained leucomonzogranite; e) "chessboard"-type textures in perthitic alkali feldspar in muscovite leucogranite; f) graphic intergrowth of quartz and alkali feldspar in pegmatite segregation in leucomonzogranite body.

#### 4.2.4 Biotite

Biotite occurs as a primary magmatic mineral in virtually all major rock types with the

exception of a few leucogranite bodies in the New Ross area of the batholith. Most grains contain variable proportions of inclusions (Plate 4.5a) including apatite, zircon, monazite and xenotime, ilmenite. It is mainly present as subhedral to euhedral groundmass grains (Plate 4.5b) in most rocks but also occurs as phenocrysts in some fine-grained leucomonzogranite units (Plate 4.5c). Euhedral biotite inclusions occur (Plate 4.5d), and may define growth planes in plagioclase and alkali feldspar megacrysts and groundmass grains. Euhedral biotite inclusions also occur in quartz in most rock types and constitute the only mode of occurrence in some leucogranites such as the East Kemptville Leucogranite (Kontak, 1990). Biotite, of secondary hydrothermal origin, occurs in some alteration zones, particularly with secondary hematite associated with vein-type U mineralization, such as at the Millet Brook U-F-P deposit (Chatterjee and Strong, 1984a; Chatterjee et al., 1982; 1985) and in the Big Indian Lake Pluton (Corey, 1988).

Biotite is commonly altered to secondary chlorite and, to a lesser extent, chlorite plus acicular crystals of rutile (Plate 4.5e). Similar textures were previously reported by MacDonald (1981) in portions of the Musquodoboit Batholith. Biotite is also altered to, and intergrown with, muscovite (Plate 4.4f) in many leucomonzogranite and leucogranite units. In fact, chlorite/muscovite intergrowths in many fine-grained leucomonzogranite and leucogranite units may represent pseudomorphic replacements of biotite grains.

Stallard (1975) documented increases in  $\text{FeO}_t/(\text{FeO}_t + \text{MgO})$  from 0.74-0.84 in the early granodiorite units to 0.80-0.90 in coarse-grained leucomonzogranite and  $>0.90$  in fine-grained leucomonzogranite. She concluded that this compositional parameter could be used to define the degree of differentiation of the host rock. This was corroborated by the results of subsequent studies of biotite in both the South Mountain (Allan and Clarke, 1981; Chatterjee et al., 1985; Kontak and Corey, 1988; Kontak, 1990) and Musquodoboit (MacDonald, 1981) batholiths.

MacDonald and Horne (1988) analysed representative biotite suites from the main rock types in the compositionally zoned Halifax Pluton. They concluded that biotite compositions, in particular the  $\text{Fe}/(\text{Fe} + \text{Mg})$  ratios, accurately reflected the whole-rock major and trace element data. They reported increases in  $\text{Fe}/(\text{Fe} + \text{Mg})$  from 0.637 in biotite granodiorite to 0.645 in biotite monzogranite, 0.641 in muscovite - biotite monzogranite, 0.750 in coarse-grained



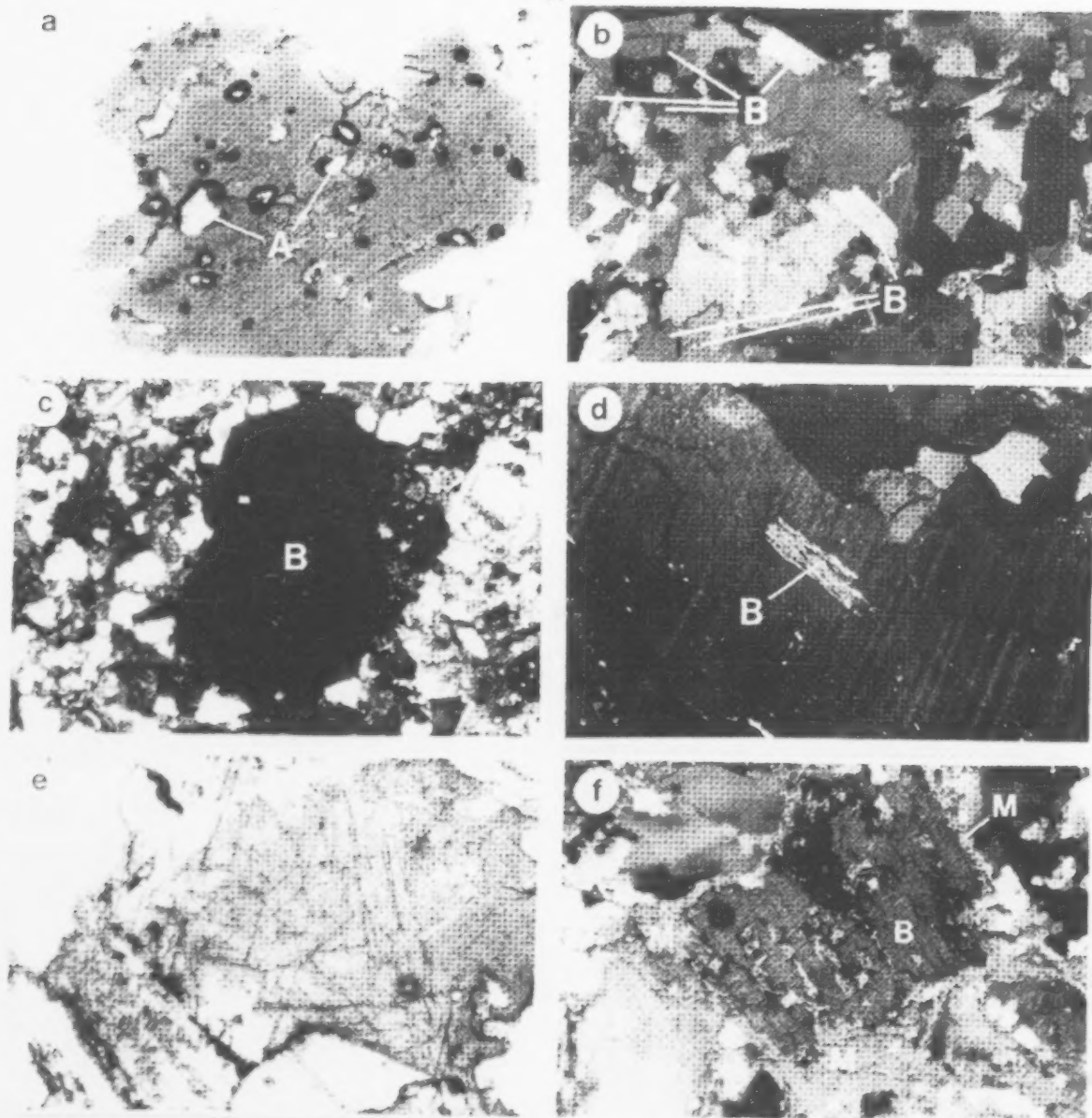


**Plate 4.5** Photomicrographs illustrating typical petrographic features of biotite (B) in the South Mountain Batholith; Length of photographs is 1 mm in a, b and c and 0.4 mm in d, e and f; all are in crossed polarized light except a and e. a) inclusion rich biotite crystal from biotite monzogranite with inclusions of apatite (A) and small inclusions of zircon?, monazite? or xenotime? with pleochroic halos in muscovite-biotite monzogranite; b) euhedral to subhedral biotite grains in biotite granodiorite; c) biotite phenocryst in porphyritic fine-grained leucomonzogranite; d) euhedral biotite inclusion in plagioclase grain in biotite granodiorite; e) pseudomorphic replacement of biotite by chlorite and acicular rutile grains; f) biotite grain altered to secondary muscovite (M) in leucogranite.

leucomonzogranite and 0.868 in fine-grained leucomonzogranite. Kontak (1990) reported iron-rich biotite compositions, with  $\text{Fe}/(\text{Fe}+\text{Mg}) = 0.96 \pm 0.014$  ( $N=15$ ), from the East Kemptville Leucogranite. Chatterjee and Strong (1984a) noted that the hydrothermal biotite in the Millet

Brook U deposit is very iron-rich when compared to magmatic biotite. Similarly, Corey (1988) reported Fe-rich biotite in a zone of high alumina hydrothermal alteration in the Big Indian Lake Pluton.

#### 4.2.5 Muscovite

As mentioned above, muscovite (or white mica) is present in all rocks of the batholith and increases systematically in modal proportions from trace amounts in biotite granodiorite to > 25% in some leucogranite units. Muscovite occurs as a secondary replacement of alkali feldspar (Plate 4.1ac, plagioclase (Plate 4.6a), andalusite (Plate 4.6b), cordierite (Plate 4.6c) and biotite in biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite and coarse-grained leucomonzogranite. In contrast, subhedral or euhedral primary magmatic muscovite (Plate 4.1d) is common in coarse- and fine-grained leucomonzogranite and predominates in leucogranite units. Muscovite is a major constituent of most greisens, where it is generally subordinate to only quartz. Muscovite greisens are ubiquitously associated with polymetallic Sn-W mineralization throughout the batholith (Plate 4.6e,f). Muscovite-rich or "ultra-greisen" pods, which occur in minor amounts throughout the batholith may contain up to > 90 modal percent muscovite (phengitic variety), such as at Inglisville (Cormier, 1988).

White mica compositions range from end-member muscovite to variable amounts of biotitic and phengitic substitution (Farley, 1979; Ham and Kontak, 1988; Corey, 1988). Clarke and Muecke (1985) noted that the composition of secondary muscovite could be correlated with the replaced mineral phase. They also concluded that muscovite interpreted as primary magmatic on basis of textural evidence could not be separated from secondary muscovite using chemical parameters. Ham and Kontak (1988) analysed representative muscovite from several textural types. They concluded that major and trace elements compositions could not be used to distinguish between primary magmatic and secondary origins for individual grains but noted that chemical parameters (e.g. F, Li, Rb, Cs) were reflective of whole-rock compositions.

#### 4.2.6 Cordierite

Cordierite is present in varying modal amounts in all rock types of the batholith but is most abundant in muscovite-biotite monzogranite and coarse-grained leucomonzogranite where it may exceed 5% of the mode. Cordierite is present as anhedral, subhedral and euhedral inclusion-free or inclusion-poor grains, in sharp contrast to the inclusion-rich porphyroblasts in the thermal

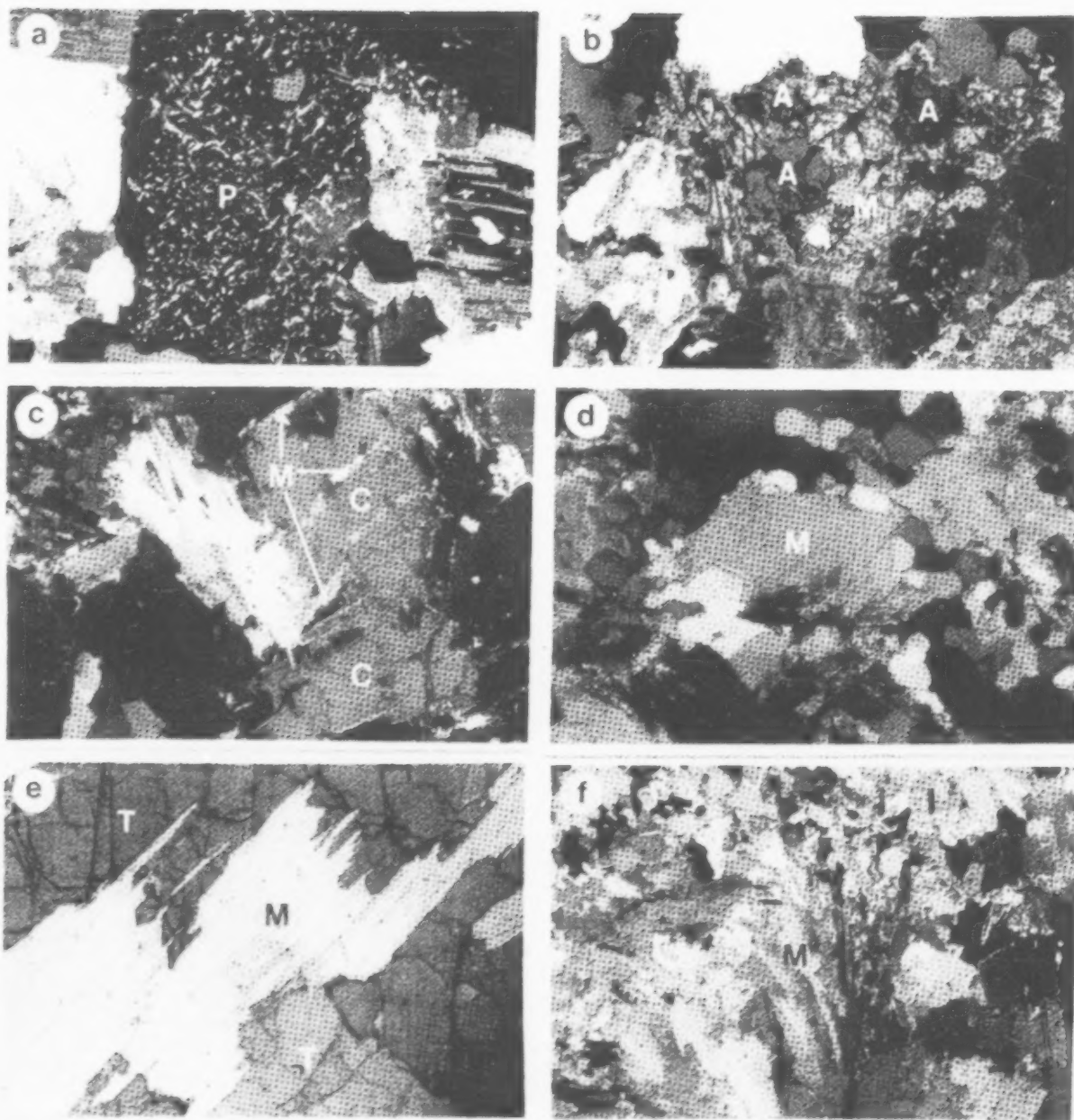


Plate 4.6 Photomicrographs illustrating typical petrographic features of muscovite (M) in the South Mountain Batholith; Length of photographs is 1 mm in all photos except 0.4 mm in b and d; all are in crossed polarized light. a) secondary muscovite replacing plagioclase (P) along crystallographic planes in leucogranite; b) secondary muscovite mantling andalusite grains (A) in biotite granodiorite; c) secondary muscovite replacing cordierite (C) along crystallographic plane in biotite granodiorite; d) euhedral (primary magmatic?) muscovite in leucogranite; e) phengitic muscovite in a quartz-muscovite-tourmaline (T) greisen; f) muscovite-rich greisen zone in outcrop of leucogranite.

metamorphic aureole surrounding the batholith. In general the occurrence of fresh cordierite

(Plate 4.7a) is restricted to biotite granodiorite, biotite monzogranite and muscovite-poor muscovite-biotite monzogranite. Cordierite in more "evolved" leucomonzogranite and leucogranite units is invariably altered to, or pseudomorphed by (Plate 4.7b), a combination of pinitite, chlorite and muscovite. MacDonald and Horne (1988) concluded that cordierite in the Halifax Pluton was very susceptible to interaction with late- or post-magmatic aqueous fluids and that the degree of replacement was crudely proportional to the amounts of secondary muscovite and feldspar replacement textures (e.g. albitization, K-feldspathization). Microprobe analyses of cordierite from the various rock types (Maillet and Clarke, 1976; unpublished data this study) indicate that cordierite was in chemical equilibrium with the various granite melts.

Cordierite is also a common constituent in aplite and pegmatite dykes where it may show well developed sector twinning. An interesting 'worm-like' intergrowth of pinitized cordierite and quartz was noted in the Tantallon Leucomonzogranite (Plate 4.7c). Large grains of muscovite and pinitite pseudomorphically replacing cordierite were also noted in leucomonzogranite dykes in the Cloud Lake Pluton. These grains have numerous poikilitic inclusions of exclusively quartz (Plate 4.7d) and are tentatively interpreted as metasomatic in origin. A similar cordierite/quartz intergrowth in the Musquodoboit Batholith was interpreted by MacDonald (1981) as a product of metasomatic alteration. Corey (1988) reported reaction rims of pinitized cordierite mantling andalusite in a high alumina alteration zone in the Big Indian Lake Pluton. These occurrences of cordierite correspond to the 'hyperaluminous' stage of crystallization as defined by Clarke (1981).

Maillet and Clarke (1985) documented a textural and chemical continuum between cordierite porphyroblasts in the thermal aureole and metasedimentary xenoliths to discrete cordierite grains in marginal biotite granodiorite biotite monzogranite units of the batholith. They concluded, on the basis of this evidence, that at least some of the cordierite of the batholith is of xenocrystic origin.

MacDonald and Horne (1988) noted that cordierite was most abundant in muscovite-biotite monzogranite and coarse-grained leucomonzogranite in the Halifax Pluton (Figure 4.3). Cordierite-rich zones (1 - > 5 % of the mode) generally parallel the zonal arrangement of rock units in the Halifax Pluton. Cordierite is most abundant in intermediate or central portions of the pluton, away from the granite/metasediment contact, in rocks with lower content of



metasedimentary xenoliths than the marginal biotite granodiorite rocks. MacDonald and Horne (1988) concluded that cordierite crystallized as a primary magmatic mineral that formed in response to critical compositional conditions in the melt, including Fe/Mg ratio and amount of alumina oversaturation in a specific zone within the Halifax Pluton magma chamber as previously described in Figure 3.2.

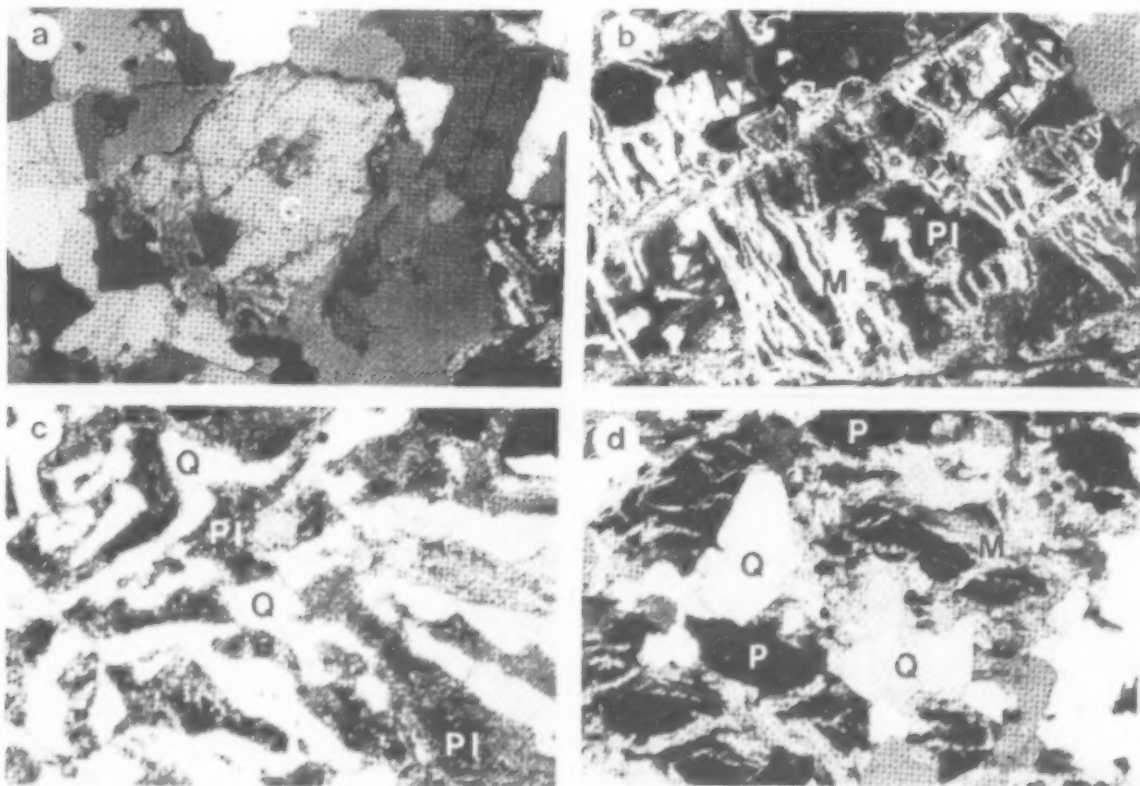


**Plate 4.7** Photomicrographs illustrating typical petrographic features of cordierite (C) in the South Mountain Batholith. Length of photographs is 1 mm in all photos; all photos are in crossed polarized light. a) unaltered cordierite grain in biotite monzogranite; b) pseudomorphic replacement of cordierite by muscovite (M) and pinite (PI) in coarse-grained leucomonzogranite; c) 'worm-like' intergrowth of quartz (Q) and pinite (PI) alteration of cordierite in leucomonzogranite dyke; d) large cordierite grains pseudomorphically replaced by muscovite (M) and pinite (PI) with abundant quartz (Q) inclusions in leucomonzogranite dyke.

Cordierite is interpreted as mostly a primary magmatic mineral in most rocks of the batholith. Additionally, cordierite in late-staged dyke rocks is interpreted as a hyperaluminous phase that crystallized in the presence of a fluid phase. Also, as documented by Maillet and Clarke (1985), some cordierite in xenolith-rich granodiorite and monzogranite is interpreted as xenocrystic in origin with subsequent chemical and possibly textural equilibration with host

granitic melts.

#### 4.2.7 Garnet

Garnet is present in trace amounts in most rock types of the batholith. Garnet in xenolith-bearing granodiorite and monzogranite units mostly has anhedral or subhedral crystal shape (Plate 4.8a) and Fe-rich, Mn-poor (almandine) compositions (Allan and Clarke, 1981; data from

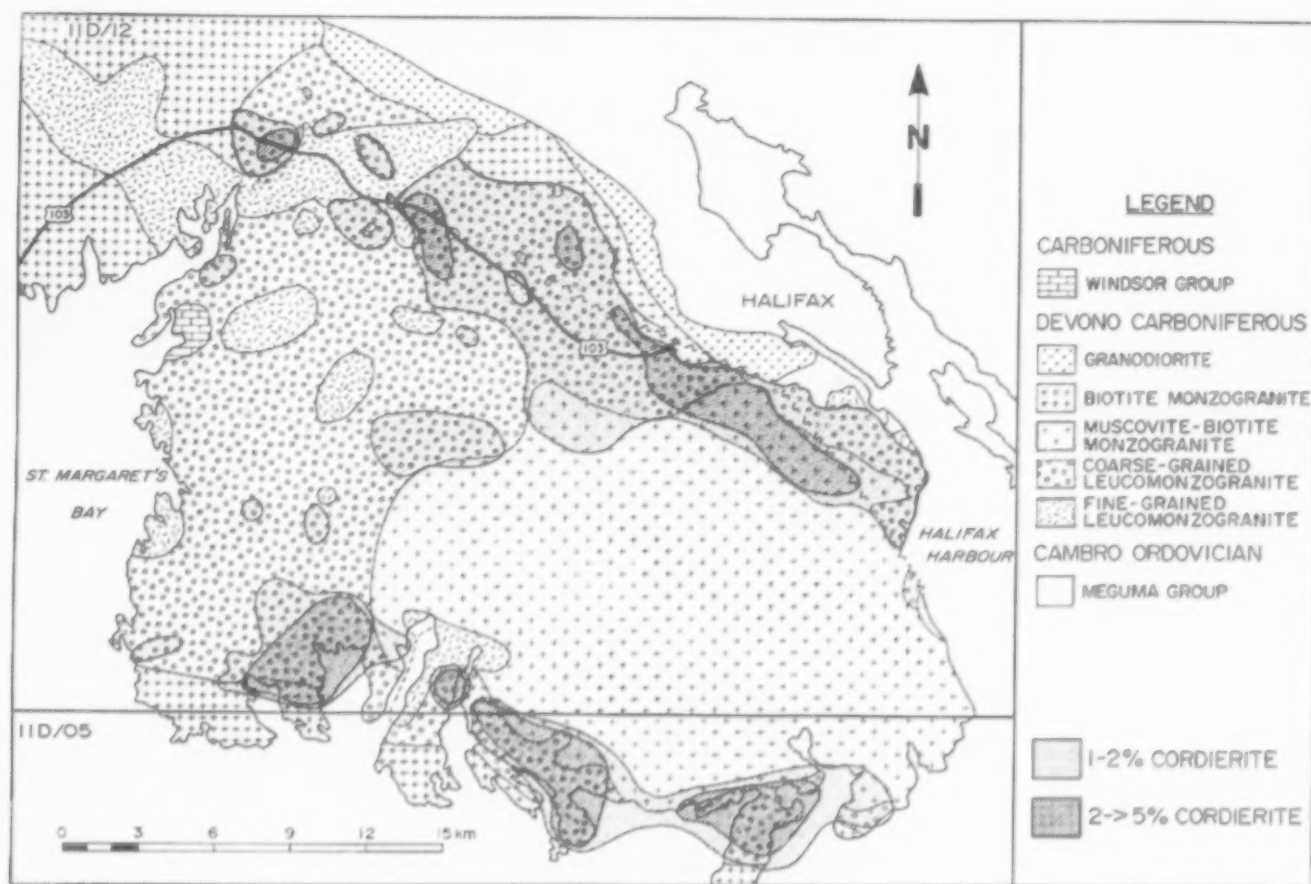


**Figure 4.3** Distribution of modal cordierite in the Halifax Pluton from point counting of stained rock slabs (400-1000 points) and visual estimates of hand specimens. Note that cordierite parallels the zoning in the pluton and is most abundant away from the granite/metasediment contact in rocks with low proportions of metasedimentary xenoliths.

this study) and is interpreted as having a xenocrystic origin. Home (1993) documented a garnet-rich zone in the margin of the Salmontail Lake biotite monzogranite, immediately adjacent to the granite/metasediment contact. It would be reasonable to propose a xenocrystic origin for this garnet-rich zone, however, the metasedimentary rocks in this area are chlorite zone of

greenschist facies metamorphism and are devoid of garnet. It is possible that chemical interaction such as introduction of alumina from metasedimentary rocks, may have initiated garnet crystallization or conversely xenocryst 'seeds' may have been incorporated in garnet grade metamorphic rocks below the present level of erosion. Both explanations are highly speculative and detailed petrographic data is required to resolve this problem.

The Boot Lake granodiorite/mafic porphyry unit (MacDonald and Ham, 1992) has a high proportion of metasedimentary xenoliths and commonly contains several modal percent subhedral to euhedral garnet (Plates 4.8b,c). The close spatial association of garnet with garnet-bearing metasedimentary xenoliths (Plate 4.8d) is in accord with the xenocrystic type of garnets as outlined by Allan and Clarke (1981). However, microprobe analyses indicate that garnets from the Boot Lake unit have reverse compositional zoning with Mn-rich rims (approximately 8-10 wt % MnO) and Fe- and Mg-rich cores (approximately 30-31 wt % FeO, 2.0-2.5 wt % MgO) that are similar to the Type III 'magmatic' garnets from Allan and Clarke (1981).

Many late-stage leucomonzogranite and leucogranite dykes throughout the batholith have small (generally <2 mm) euhedral, orange coloured garnets (Plate 4.8e). Allan and Clarke (1981) analysed several of this textural variety of garnet and reported overall compositions and reverse zoning similar to those in the Boot Lake unit. They concluded that these garnets crystallized as primary magmatic minerals. The presence of albitic plagioclase, abundant secondary muscovite and chloritic alteration of biotite in many garnet-bearing leucomonzogranite dykes is interpreted as reflecting the presence of late-magmatic fluid(s). Therefore garnet may represent a 'hyperaluminous' phase in these rocks, as outlined by Clarke (1981).

Kontak and Corey (1988) reported anhedral or pseudo-euhedral garnet-quartz intergrowths from the Big Indian Lake Pluton (Plate 4.8f). They noted that garnet was invariably intergrown with only quartz, mantled by muscovite selvages. They also noted that garnet-quartz intergrowths were invariably surrounded by leucocratic biotite-free zones. Microprobe analyses of garnet from the Big Indian Lake leucomonzogranite indicated spessartite-rich compositions (15-25 mole %) and normal and reverse zoning and unzoned compositional profiles. Kontak and Corey (1988) concluded that these garnets were clearly metasomatic in origin resulting from the pervasive interaction of late magmatic fluids (500° - 550° C) with the leucomonzogranite host. They noted that the compositional similarities to garnets from elsewhere in the batholith that were interpreted

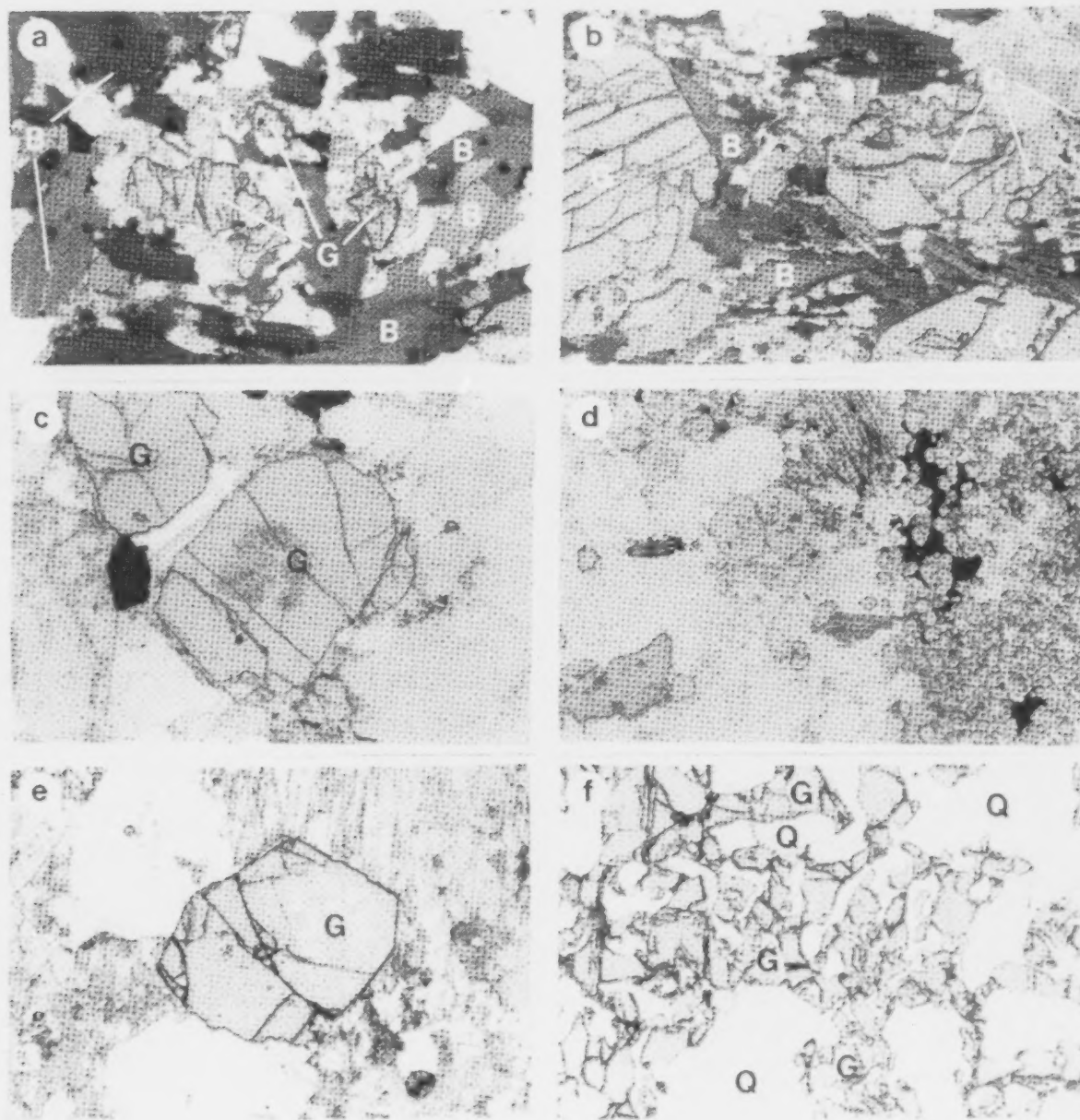


**Plate 4.8** Photomicrographs illustrating typical petrographic features of garnet (G) in the South Mountain Batholith; Length of photographs is 1 mm in all photos; all are in plane polarized light: a) anhedral xenocrystic garnet in biotite-rich (B) "clot" in biotite granodiorite; b) large garnet grains in biotite granodiorite. Note the strong parallel alignment of biotite (B) grains that define a planar fabric in the Boot Lake granodiorite/mafic porphyry (MacDonald and Ham, 1992); c) garnet with inclusion-rich (restite?) core and clear, inclusion-free rims in biotite granodiorite; d) garnet-bearing biotite granodiorite (left side of photomicrograph) in contact with garnet-rich metasedimentary xenolith (right side of photomicrograph). May represent xenocrystic "seeding" from xenolith to granodiorite; e) euhedral spessartite-rich (magmatic?) garnet in fine-grained leucomonzogranite dyke; f) metasomatic intergrowth of garnet and quartz (Q) in the Big Indian Lake Pluton (Kontak and Corey, 1988).



as primary 'magmatic' by previous workers, raised questions regarding the overall origin of garnets in the batholith.

In summary, the results of petrographic studies of garnet indicate it may have formed by xenocrystic, magmatic, hyperaluminous or metasomatic processes.

#### 4.2.8 Andalusite

The occurrence of andalusite in the South Mountain Batholith was first reported by Wright (1931) and later Kent (1962), McKenzie (1974), Charest (1976) MacDonald and Horne (1988), Corey (1988) and MacDonald et al. (1992). Andalusite is restricted to coarse- and fine-grained leucomonzogranite (0-trace amounts) and leucogranite (0-0.6 modal %) where it occurs as small (generally <1 mm) inclusion-free interstitial crystals. It is mainly mantled by muscovite selvages or poikilitically enclosed in larger muscovite grains although some grains are in contact with other minerals including biotite, plagioclase and quartz. Some andalusite cores have pale pink pleochroism which reflects compositional zonation with Fe-rich cores (unpublished data this study). Muscovite rims are interpreted secondary subsolidus replacement products of andalusite. Clarke et al. (1976) noted that the andalusite in the batholith was texturally dissimilar to the inclusion-rich andalusite (chiastolite variety) in the thermal metamorphic aureole. Based mainly on this and the compositions of co-existing biotite, Clarke et al. (1976) concluded that andalusite in 2-mica leucomonzogranite rocks from the New Ross, East Dalhousie and West Dalhousie Plutons crystallized as a primary magmatic mineral. Clarke (1981) concluded that the presence of andalusite in peraluminous granitic rocks is a mineralogical expression of alumina oversaturation.

Corey (1988) reported an occurrence of andalusite in a NE-trending fracture-controlled zone of high alumina hydrothermal alteration in the Big Indian Lake Pluton that is also host to U-Cu mineralization. Andalusite constitutes up to 20% of the mode and is present as large euhedral grains (<2.5 cm) with sericite and/or plagioclase rims. Other co-existing mineral phases in the alteration zone include sillimanite, spinel (hercynite-rich), muscovite, chalcopyrite, pyrite, covellite, sphalerite and light green apatite. Corey (1988) reported compositional zoning in andalusite which consisted of Fe-rich (0.54-1.99 wt % FeO), pink pleochroic cores and clear Fe-poor (0.41-0.61 wt % FeO) rims. He concluded on textural and compositional grounds that the andalusite and other minerals in

the alteration zone formed from the interaction of a Na-( $\pm$ Al-) rich fluid phase with the host coarse-grained leucomonzogranite

#### 4.2.9 Topaz

The occurrence of topaz in the batholith is restricted to trace to 0.7% in leucogranite bodies from the New Ross Pluton (Keddy Reeves, Burnt Blanket, Lake Lewis leucogranites), trace amounts in the Murphy Lake leucogranite of the East Dalhousie Pluton (MacDonald et al., 1992; Clarke et al., 1993) and up to 8% in the East Kemptville Leucogranite of the Davis Lake Pluton (Kontak, 1990). Topaz in these leucogranites is primarily subhedral to euhedral and is approximately equidimensional with quartz and feldspars.

Topaz is a major constituent of greisen zones in the East Kemptville deposit (Richardson et al., 1982; Kontak, 1990). The occurrence of topaz in hydrothermally altered zones elsewhere in the batholith is generally restricted to a few locales in the New Ross Pluton including the Keddy-Reeves and Walker Moly occurrences (Charest, 1976; Farley, 1979; O'Reilly et al., 1982).

Kontak (1990) analysed topaz from the East Kemptville Leucogranite and associated greisens. He noted that topaz is essentially unzoned and that there is no compositional difference between topaz in the leucogranite and in greisen. Calculated  $F/(F + OH)$  ratios ( $0.80 \pm 0.05$ ) were noted to be consistent with high temperatures of formation which, along with textural observations, prompted Kontak (1990) to conclude that topaz formed as a primary magmatic mineral phase.

#### 4.3 Mineralogical Zoning in Stage I and II Plutons

Spatial variations in the modal proportions of several mineral phases including muscovite, biotite, cordierite and the relative proportions of quartz-alkali feldspar-plagioclase define normal and reverse compositional zoning in most of the Stage I and II Plutons (Table 3.2). Normal and reverse compositional zoning are defined as systematic increase and decrease, respectively, in degree of differentiation from the margin to the core of a pluton. In addition, cryptic compositional zoning is defined by the mineral chemistry of several phases including biotite and plagioclase.

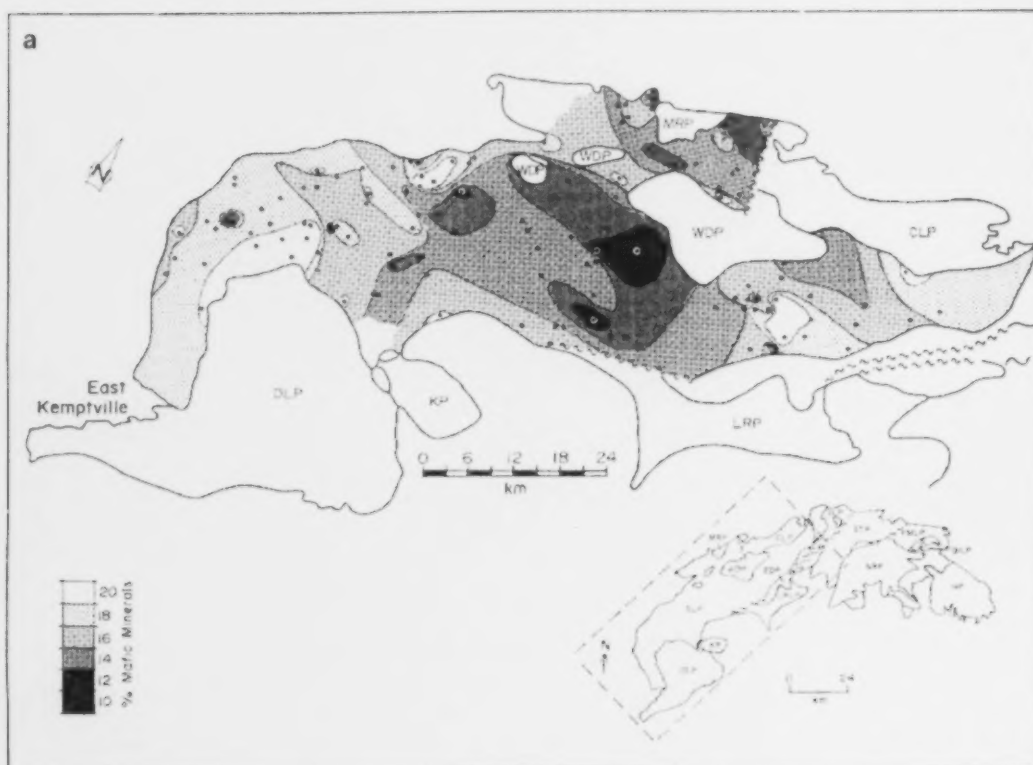
As mentioned in previous sections, Macdonald and Horne (1988) measured very systematic changes in the modal proportions of biotite, cordierite (Fig. 4.3) and muscovite which defined both normal and reverse compositional zoning in the Halifax Pluton. In addition, they noted that the same

normal and reverse zoning trends could be defined using the  $\text{Fe}/(\text{Fe} + \text{Mg})$  ratio of biotite and the anorthite/albite content of plagioclase. They noted that these mineralogical characteristics were very similar to the trends for major and trace elements in the Halifax Pluton (see Chapter 5 for further discussion).

Horne et al. (1991) studied the modal variation of mafic minerals, consisting mainly of biotite with minor cordierite and garnet in the Scrag Lake Stage I Pluton. They noted that the modal percentage of mafic minerals ranged from 9.7% to 24.6% with approximately 70% of the samples in their study ranging from 14% to 20%. A contour plot for their data (Figure 4.4a) reveals systematic modal variations which were interpreted as reflecting compositional zoning within the pluton. In general, the central portion of the pluton, near the West Dalhousie pluton has the lowest modal amounts of mafic minerals (<10 - 12%) and is therefore the most "evolved" portion of the pluton (i.e. normal zoning). In contrast there are several areas of the pluton that have high modal amounts of mafic minerals. These are mainly along the margin of the pluton such as near the Davis Lake and East Dalhousie Plutons which is consistent with normal zoning. However, some 'mafic' portions of the pluton are in central parts of the pluton thus indicating reverse compositional zoning. Horne et al. (1991) noted a strong correlation between the percentage of mafic minerals and the equivalent Th/equivalent K (eTh/eK) Gamma Ray Spectrometric data (Geological Survey of Canada, 1977, Figure 4.4b). Areas of the pluton with low eTh/eK correlate with the lowest mafic mineral contents. Highest values of eTh/eK occur in areas with the highest mafic mineral content. Horne et al. (1991) proposed that the eTh/eK was a better estimate of the petrographic variation in the Scrag Lake Pluton, and presumably other Stage I plutons in the batholith. The observed variations in eTh/eK (Figure 4.4b) reveal complex compositional zoning trends throughout this pluton.

In summary, normal and reverse compositional zoning in Stage I and Stage II plutons has been defined using both the modal percentages of various mineral phases and the variations in mineral chemistry.

**Figure 4.4** (next page) a) Contour plot of modal percentages of mafic minerals (biotite, cordierite, garnet) in the Scrag Lake Pluton. Modal data was determined from point counting (approximately 600 to 2000 points depending upon sample size) of stained and unstained rock slabs. For a list of pluton designations the reader is referred to Figure 2.3 (in pocket at back). b) Airborne equivalent Th/equivalent K gamma ray spectrometric data (Geological Survey of Canada, 1977) for the Scrag Lake Pluton (after Horne et al., 1991).





#### 4.4 Summary and Discussion

Detailed petrographic studies of the six main rock types indicate that rocks of the various plutons have similar mineralogical characteristics. For example, the presence of biotite, muscovite, aluminosilicate (e.g. andalusite), cordierite, garnet and tourmaline, in virtually all of the plutons, is consistent with the "characteristic" mineral assemblage for peraluminous granites as defined by Clarke (1981). This same mineral assemblage, in particular the abundance of cordierite (up to 5%), combined with the absence of hornblende and titanite is consistent with "S-type" granitoids as described by Chappell and White (1974) and White et al. (1986). The only occurrence of magnetite in the entire batholith is in a single sample of albite-magnetite breccia from a drill hole near the East Kemptville deposit (Richardson, 1988) where the presence of intense alteration and deformation suggests a post-magmatic origin for the assemblage. The ubiquitous occurrence of accessory ilmenite, along with muscovite and low Mg/Fe biotite, is consistent with the "ilmenite-series" granitoids as described by Ishihara (1977).

Detailed investigations indicate that although most major rock-forming mineral phases are of magmatic origin, many minerals also formed by xenocrystic, hyperaluminous or metasomatic processes at various stages in the evolution of the batholith. Therefore the exact origin of a mineral phase in any given rock must be evaluated individually to establish its origin.

In spite of the overall textural and mineralogical similarities throughout the batholith, several plutons display unique petrographic features. For example, the ubiquitous metasomatic garnet (reaction relationship with biotite) in both the fine- and coarse-grained leucomonzogranite rocks of the Big Indian Lake pluton (Kontak and Corey, 1988) and rare to absent in the other twelve plutons. Similarly, trace amounts of secondary, metasomatic sillimanite (primarily fibrolite) are unique to the Big Indian Lake pluton (Corey, 1988b). Accessory titanite and epidote occur as inclusions, along with zircon, apatite, monazite and ilmenite, in biotite of the Davis Lake pluton and a cumulate phase from the Big Indian Lake pluton. Neither titanite nor epidote have been reported in any of the other eleven plutons. These mineralogical features suggest that different physico-chemical conditions ( $T$ ,  $P_{H_2O}$ ,  $fO_2$ , bulk composition) prevailed in the various plutons.

## Chapter 5

### GEOCHEMISTRY

Prior to the South Mountain Batholith project there were numerous geochemical studies of the South Mountain Batholith including Smith (1974), McKenzie and Clarke (1975), Smith (1979), Muecke and Clarke (1981), Chatterjee and Muecke (1982), Chatterjee and Strong (1984a,b), Clarke and Muecke (1985), Clarke and Chatterjee (1988). In general these studies involved either small sample populations (i.e.  $< \text{ca. } N=30$ ) that were used to characterize the compositions of the major rock types in the batholith or larger sample suites (e.g.  $\text{ca. } N=100-200$ ) that were collected in localized areas of the batholith. A large number of samples ( $N=597$ ) were collected and analyzed for a suite of major and trace elements as part of the South Mountain Batholith project. The main aims were to define the complete compositional range for each of the rock types in the sundry plutons, defined during mapping, and to determine if any spatial compositional trends (i.e. zoning) could be delineated. The following sections outline: the sampling and analytical methods used in the South Mountain Batholith project; the geochemical characteristics of the major rock types in the batholith; the nature of chemical zoning in both Stage I and II plutons; and the geochemistry of leucogranite, mafic porphyry and dyke rocks.

#### 5.1 Methodology

A total of 597 large (approximately 25 kg) samples from the entire batholith were chosen for major and trace element chemical analysis. Wherever possible, samples were collected from blasted roadside outcrop. In more remote areas, mainly along secondary and bush roads, it was necessary to drill and blast outcrop to acquire "fresh" or unweathered material for analysis. Two

sample suites were collected: 1) representative samples of the seven major rock types which were selected on the basis of results of systematic geological mapping, investigation of stained slabs, detailed petrography and outcrop distribution; and 2) samples of aplite, mineralized and barren pegmatite dykes, alteration zones and mineralized greisens, veins and breccias.

Whenever possible, a minimum of 25 kg of material was collected from large outcrop areas to eliminate potential problems of heterogeneity. Clearly, for some of the dykes and mineralized zones this was not possible and much smaller samples were collected. Samples were then crushed to minus 2.5 cm, homogenized and then approximately 4 kg of fresh material was handpicked to eliminate weathering, fracture-related alteration and xenoliths. The hand-picked material was then ultrasonically cleaned, dried, crushed to minus 5 mm and split to form a 200 gm subsample which was subsequently crushed in a ceramic shatter box to minus 200 mesh.

Bench standards were prepared for quality control in the analytical procedures. Standard NIC-1 is a medium grained, non megacrystic biotite granodiorite which was collected in a rock quarry in a satellite intrusion north of the batholith, near Nictaux (MacDonald and Ham, 1992). Standard ASPO-2 is a sample of the Sandy Lake biotite monzogranite (Corey, 1990) which was collected along Highway #103, north of the Aspotogan peninsula. Approximately 200 kg of fresh material was collected and crushed according to the above procedure. Mean values and standard deviations for trace and major element compositions for the two standards are presented in Table 5.1.

Samples, analytical splits and bench standards were sent to the Regional X-Ray fluorescence (XRF) facilities at St. Mary's University for analysis of major elements including  $\text{SiO}_2$ ,  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MnO}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$  and  $\text{P}_2\text{O}_5$  and a suite of trace elements

(Ba, Rb, Sr, Y, Zr, Nb, Pb, Zn, Cu, Ni, V and Cr). Major element concentrations were determined using fused glass discs whereas pressed powder pellets were used for trace element determinations. The same suite of samples and standards were sent to Bondar-Clegg Laboratories for determination of 12 additional trace elements. Analytical procedures included: Instrumental Neutron Activation Analysis (INAA) for Sc, As, La, Hf, Ta, W, Th and U; Atomic Absorption (AA) for Li; Specific Ion Electrode for F; DC Plasma Emission Spectroscopy for B; and X-Ray fluorescence for Sn. Several sample subsets were sent to the analytical facility at Memorial University in Newfoundland for analysis of rare earth elements (REE). Samples were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) using a sodium peroxide ( $\text{Na}_2\text{O}_2$ ) sinter digestion.

## 5.2 Results

### 5.2.1 Geochemistry of Major Rock Types

Complete analytical results, with the exception of REE results, are given in Ham et al. (1989, 1990). Average major and trace element compositions and normative mineralogy, with standard deviations, for the major rock types in the five Stage I and eight Stage II plutons are presented in Tables 5.1 and 5.2. Complete analytical results for individual plutons are given in Appendix A. The analytical errors are  $\leq 2\%$  for the major elements and  $\leq 10\%$  for most of the trace elements with the exception of Pb, Hf, Ta, La, Th and U where errors are  $\leq 20\%$  of the reported values. A complete discussion of all geochemical characteristics for all samples analyzed during this project is beyond the scope of this report. Consequently the following section will focus on the average rock type compositions for Stage I and II plutons and also the compositional trends in selected plutons.



A significant geochemical parameter for granitic rocks is the Shand Index value which separates rocks into peraluminous, metaluminous and peralkaline groups. Average rock type compositions for Stage I and II plutons have been plotted on a Shand-type diagrams (Figs 5.1a,b). Clearly all of the rocks of the batholith are peraluminous (i.e. molecular  $\text{Al}_2\text{O}_3/(\text{CaO}+\text{K}_2\text{O}+\text{Na}_2\text{O}) > 1$ ) with average A/CNK values ranging from 1.05 to 1.45. There is large overlap in the average A/CNK and A/NK values for the various rock types, however, it should be noted that the lowest average A/CNK values (1.05-1.10) are for mafic porphyry and biotite granodiorite units whereas the highest average values (1.40-1.45) are for muscovite leucogranites suggesting a relationship between "degree of differentiation" and alumina oversaturation. It should be also noted that these data contrast predicted results if the "restite unmixing" process of Chappell and White (1974) and White et al. (1986) is employed to explain chemical changes in the batholith. That is, the rocks with the highest proportion of metasedimentary xenoliths (restite) should have the highest A/CNK values. It should also be noted that all rocks of the batholith have relatively high  $\text{SiO}_2$  and low CaO, when compared to other worldwide granite massifs, with average concentrations ranging from 67.12% (SD-1.73) and 1.94% (SD-0.46), respectively, in granodiorite to 73.62% (SD-0.89) and 0.39 (SD-0.14), respectively, in leucogranite rocks.

Several overall major element "trends" have been previously been noted in both Stage I and II plutons (MacDonald and Horne, 1988; Chatterjee and Horne, 1991; MacDonald et al., 1992). To demonstrate this feature, Harker variation diagrams have been prepared for the five Stage I and eight Stage II plutons (Figs 5.2a,e and 5.3a,h).

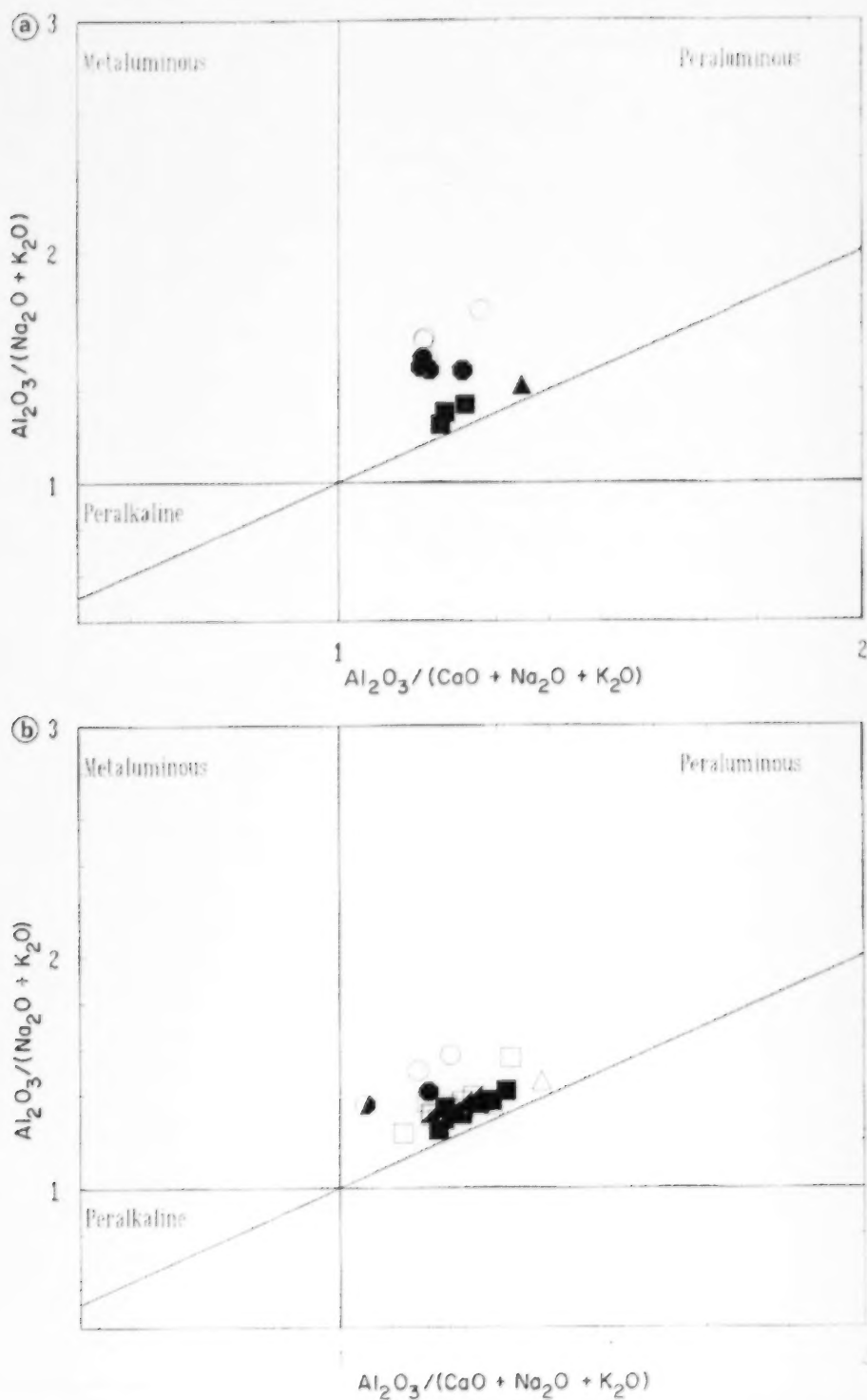


**Figure 5.1** Plot of average A/CNK (i.e. molecular  $\text{Al}_2\text{O}_3 / (\text{CaO} + \text{K}_2\text{O} + \text{Na}_2\text{O}) > 1$ ) versus A/NK for the major rock types of the South Mountain Batholith (after Shand, 1931). a) Stage I plutons; b) Stage II plutons. All rocks are peraluminous.

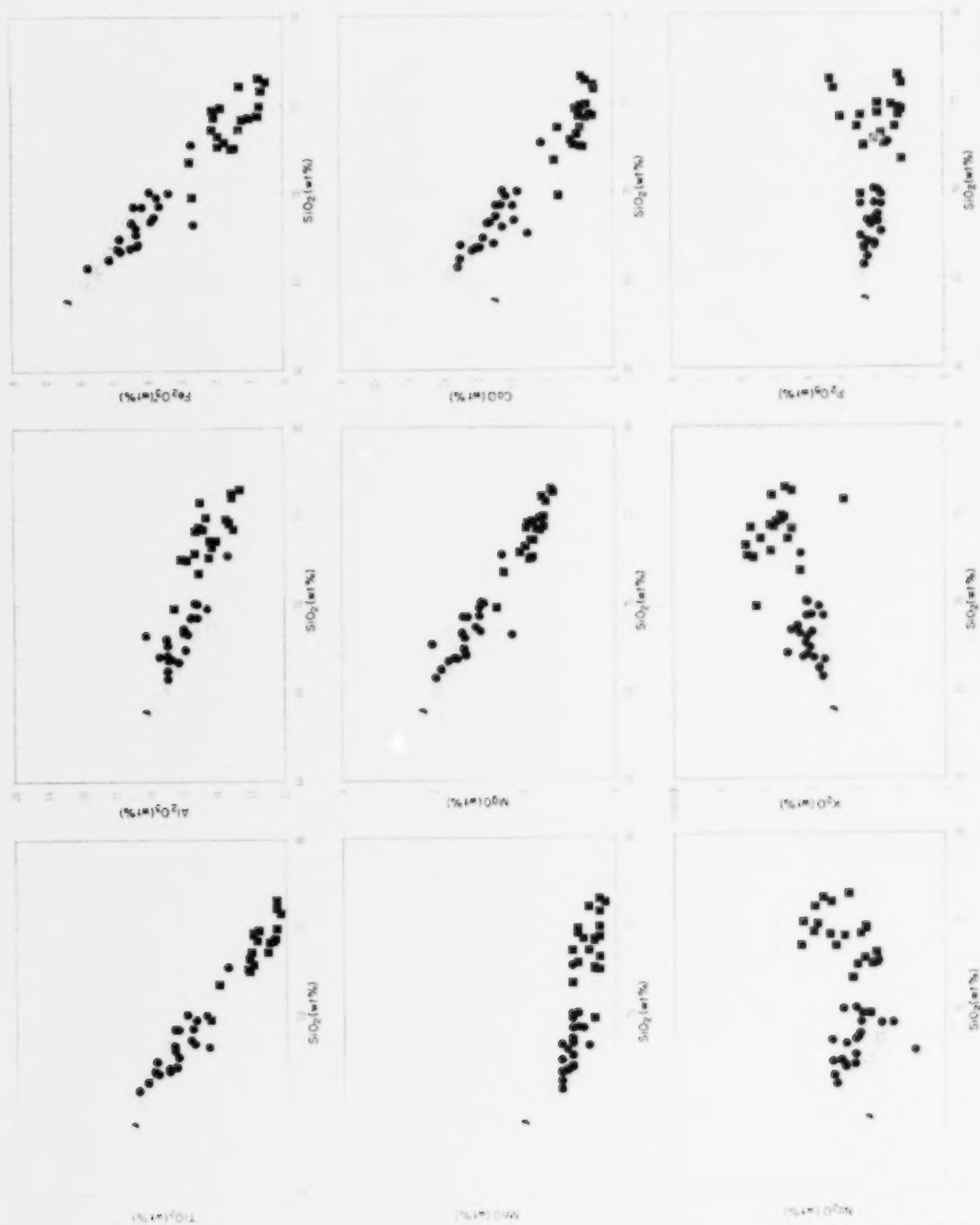


Figure 5.2a Harker variation diagrams for the Scrag Lake Stage 1 pluton.

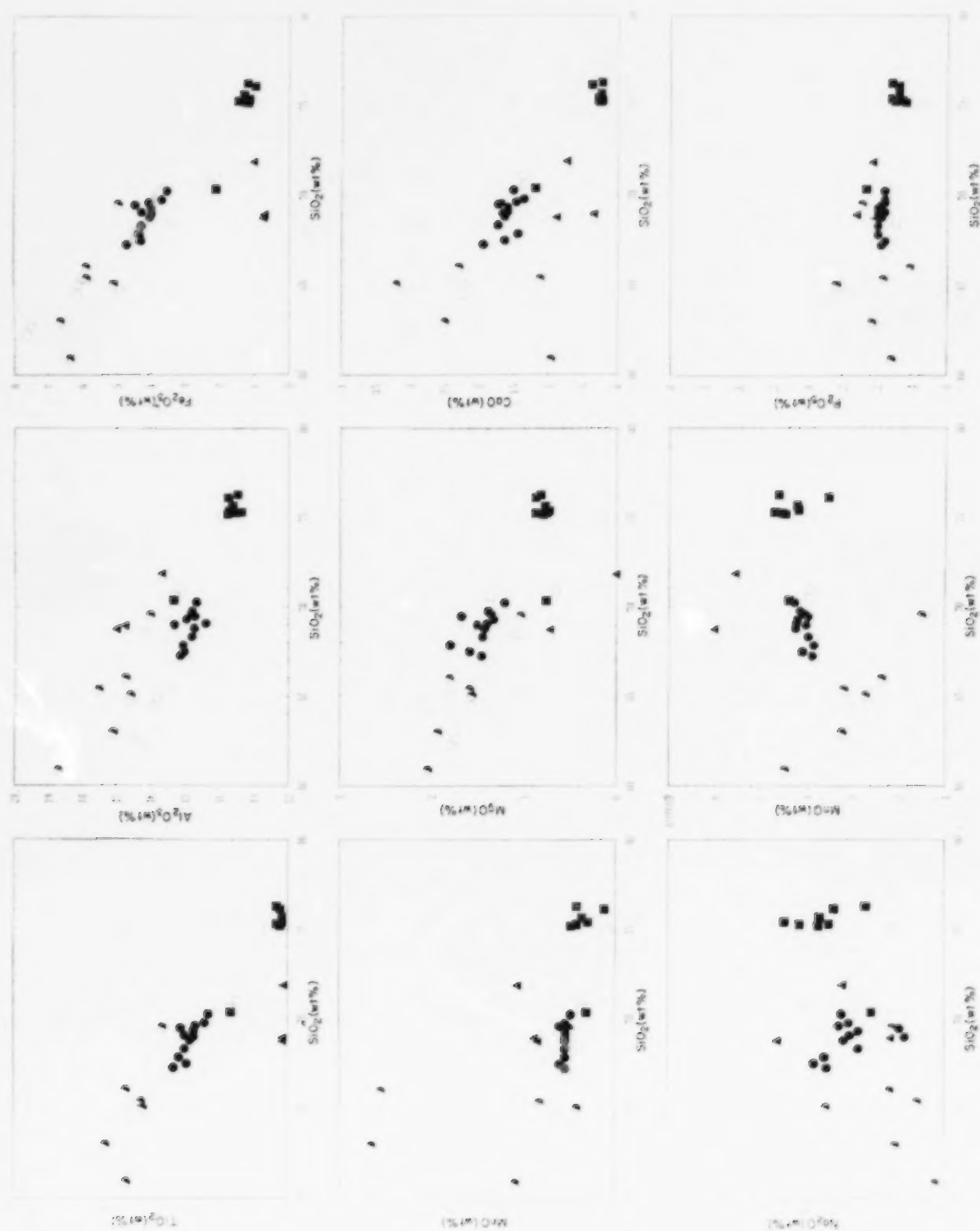


Figure 5.2b Harker variation diagrams for the Cloud Lake Stage I pluton.



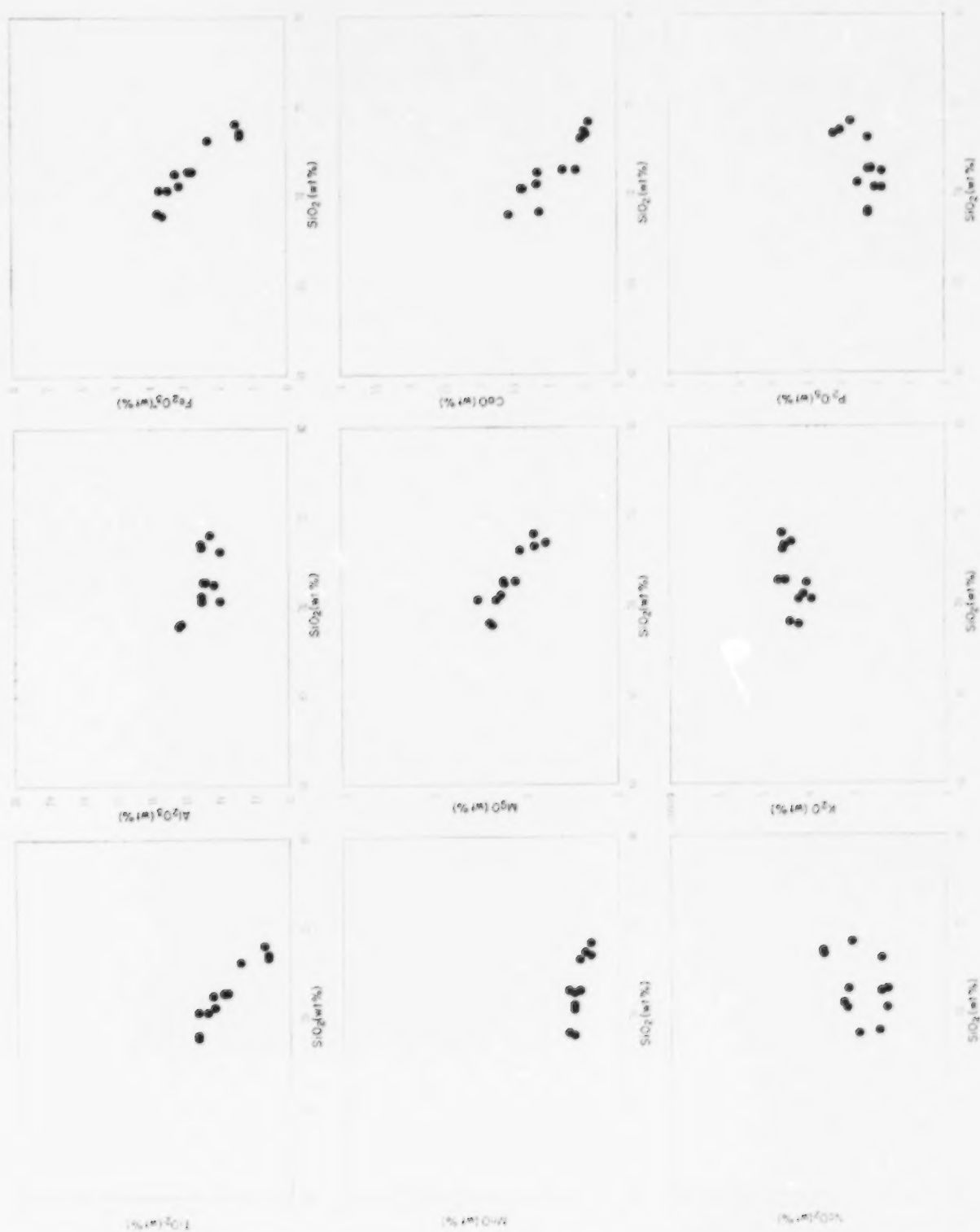


Figure 5.2c Harker variation diagrams for the Little Round Lake Stage I pluton.

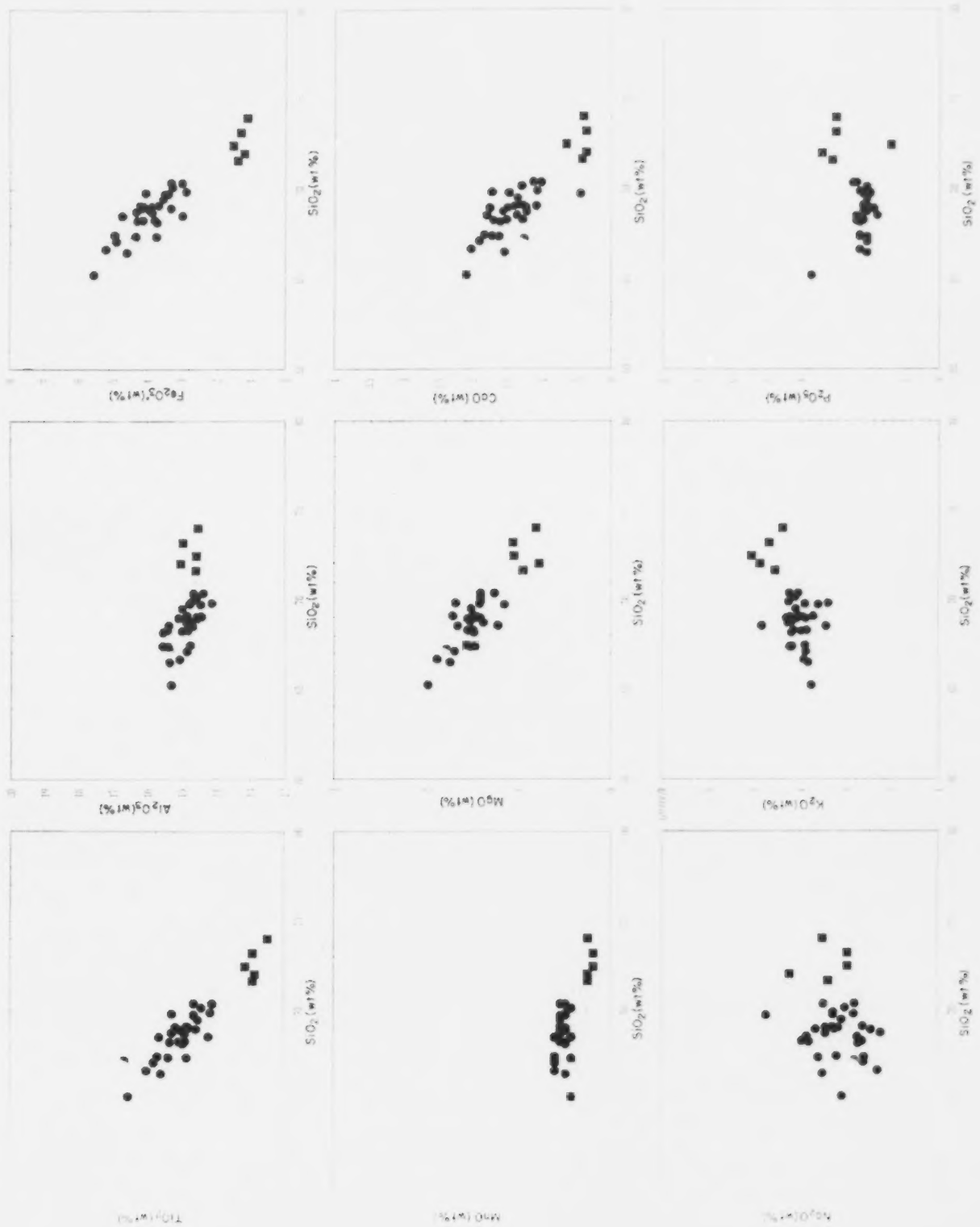


Figure 5.2d Harker variation diagrams for the Salmon Lake Stage I pluton.



Figure 5.2e Harker variation diagrams for the Five Island Lake Stage 1 pluton.

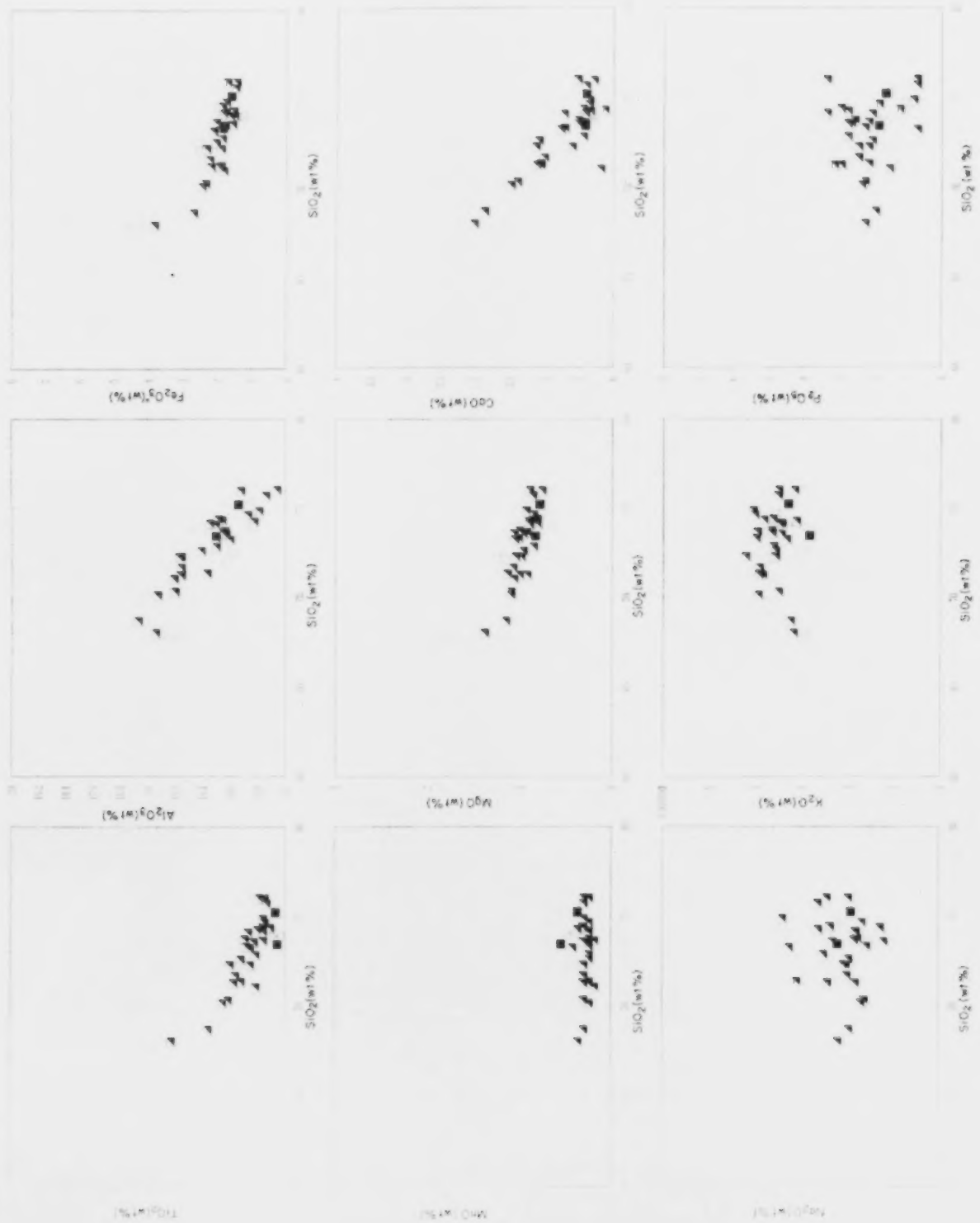


Figure 5.3a Harker variation diagrams for the Davis Lake Stage II pluton.



Figure 5.3b Harker variation diagrams for the Kejimikujik Stage II pluton.





Figure 5.3c Harker variation diagrams for the West Dalhousie Stage II pluton.



Figure 5.3d Harker variation diagrams for the Morse Road Stage II pluton.

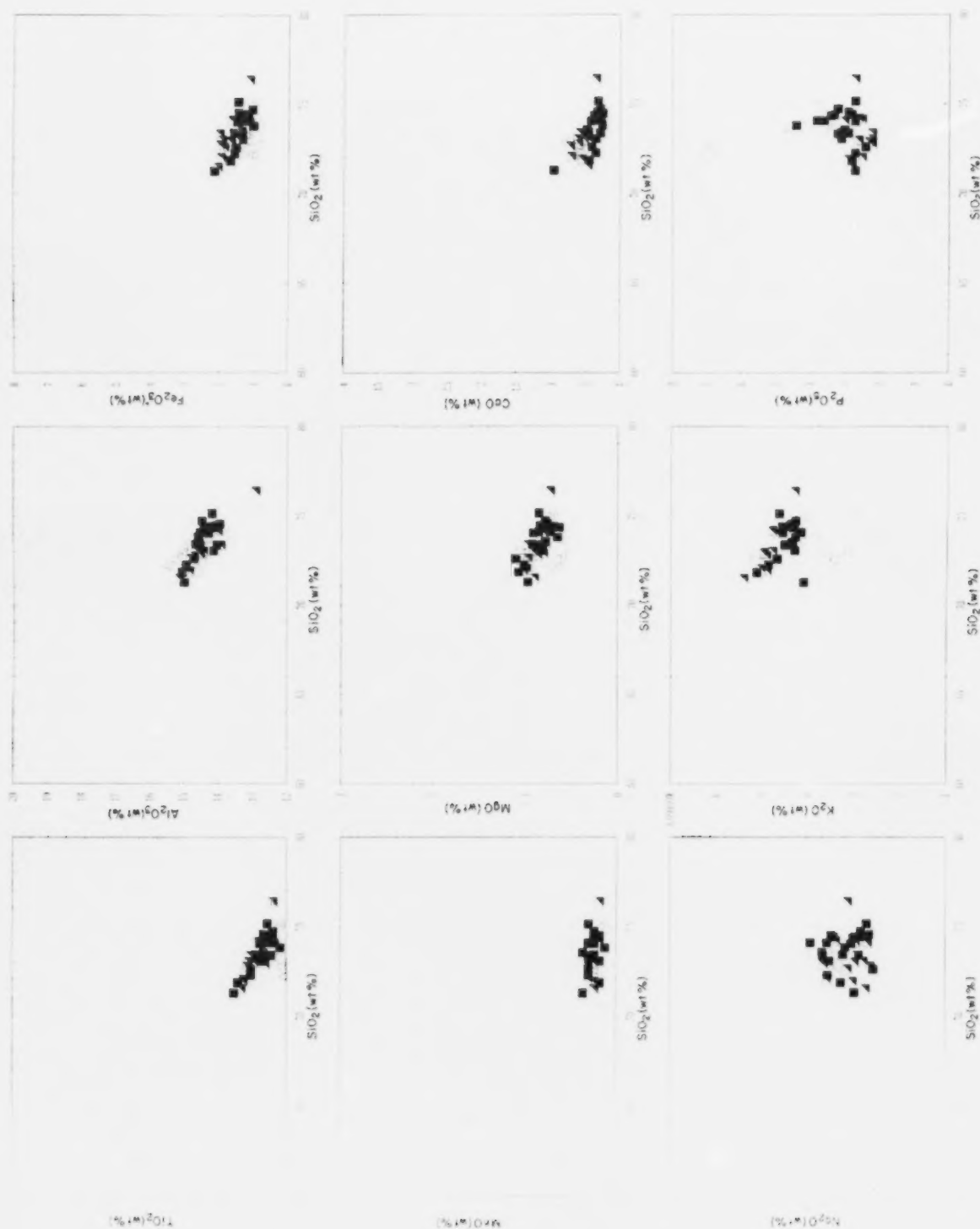


Figure 5.3e Harker variation diagrams for the East Dalhousie Stage II pluton.



Figure 5.3f Harker variation diagrams for the New Ross Stage II pluton

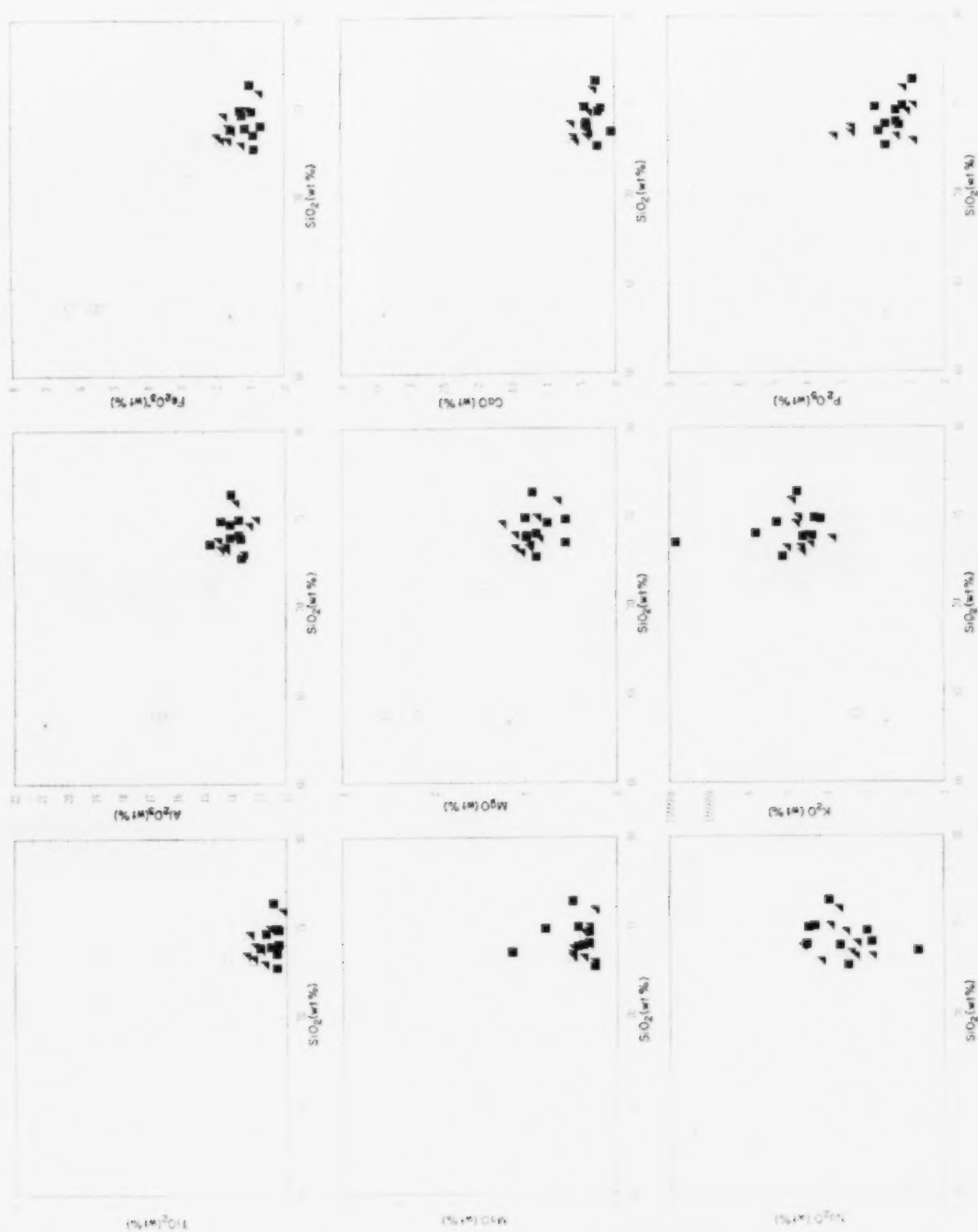


Figure 5.3g Harker variation diagrams for the Big Indian Lake Stage II pluton.



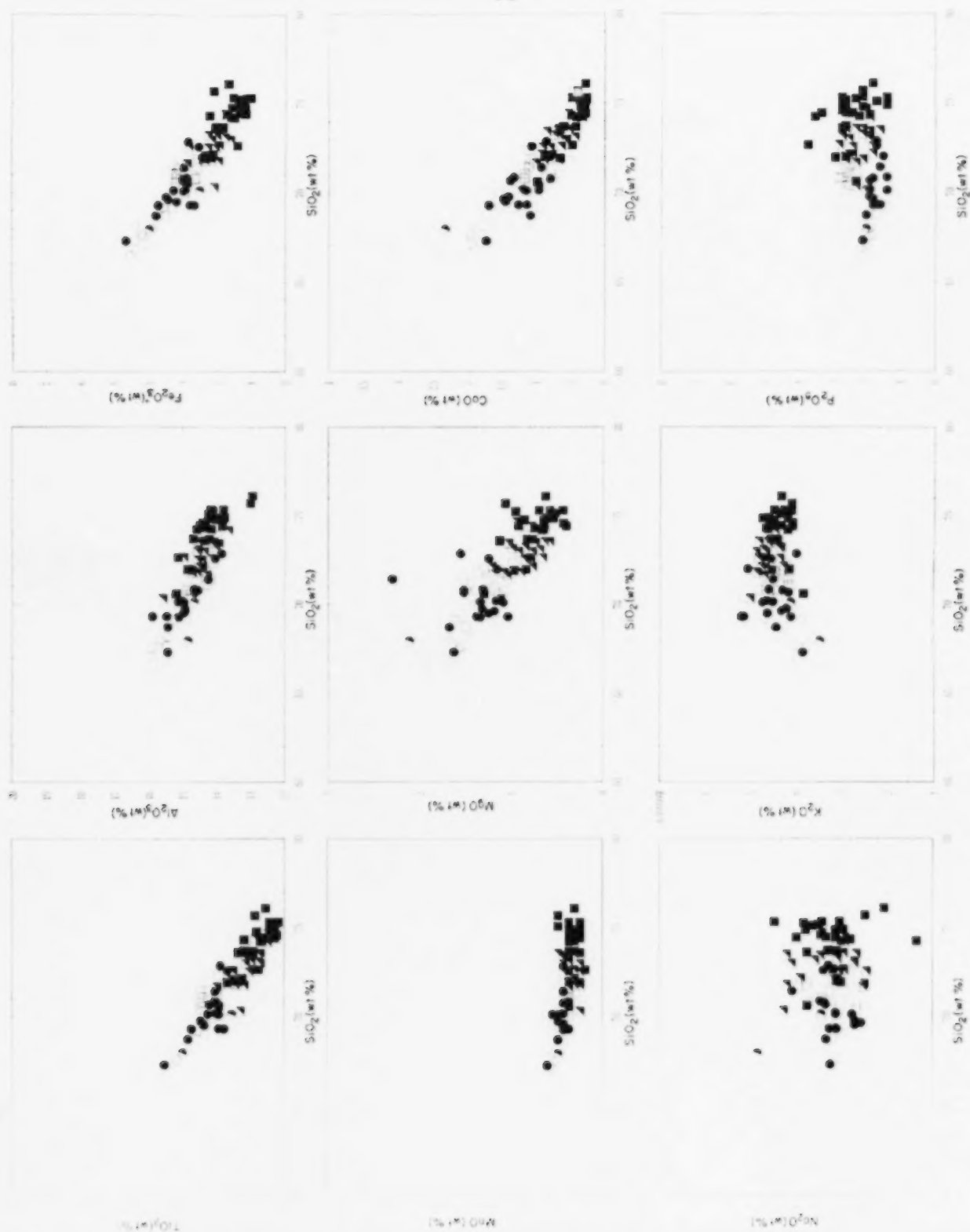


Figure 5.3h Harker variation diagrams for the Halifax Stage II pluton.

Table 5.1 Average major and trace element geochemistry and normative mineralogy of Stage I plutons

| Pluton                         | Cloud Lake (CLP) |       |       | Five Island Lake (FIL) |       | Little Round Lake (LRP) |       |
|--------------------------------|------------------|-------|-------|------------------------|-------|-------------------------|-------|
| Rock Type                      | BGD              | BMG   | FGLMG | BGD                    | APLI  | BMG                     | FGLMG |
| % of Pluton                    | 8.4              | 81.4  | 10.2  | 99.9                   | 0.1   | 0                       | 0     |
| Samples                        | 4                | 12    | 7     | 20                     | 3     | 9                       | 3     |
| Major Elements (wt %)          |                  |       |       |                        |       |                         |       |
| SiO <sub>2</sub>               | 65.38            | 68.82 | 75.58 | 67.35                  | 73.65 | 70.69                   | 73.62 |
| Al <sub>2</sub> O <sub>3</sub> | 16.49            | 14.87 | 13.60 | 15.59                  | 14.38 | 14.47                   | 14.44 |
| Fe <sub>2</sub> O <sub>3</sub> | 4.87             | 4.15  | 1.23  | 4.26                   | 1.69  | 3.17                    | 1.38  |
| CaO                            | 1.94             | 1.60  | 0.27  | 2.06                   | 0.28  | 1.07                    | 0.44  |
| MgO                            | 1.84             | 1.47  | 0.80  | 1.89                   | 0.89  | 1.28                    | 0.86  |
| Na <sub>2</sub> O              | 3.36             | 3.35  | 3.77  | 3.53                   | 3.08  | 3.12                    | 3.64  |
| K <sub>2</sub> O               | 3.63             | 4.08  | 4.33  | 3.56                   | 4.68  | 4.27                    | 4.47  |
| TiO <sub>2</sub>               | 0.70             | 0.53  | 0.04  | 0.64                   | 0.13  | 0.42                    | 0.13  |
| P <sub>2</sub> O <sub>5</sub>  | 0.21             | 0.19  | 0.14  | 0.21                   | 0.18  | 0.21                    | 0.30  |
| MnO                            | 0.11             | 0.09  | 0.06  | 0.08                   | 0.02  | 0.08                    | 0.05  |
| H <sub>2</sub> O               | 0.95             | 0.34  | 0.42  | 0.69                   | 1.33  | 0.65                    | 0.64  |
| Normative Mineralogy           |                  |       |       |                        |       |                         |       |
| Q                              | 26.05            | 28.87 | 35.76 | 26.76                  | 36.75 | 32.99                   | 34.16 |
| OR                             | 21.84            | 24.33 | 25.65 | 21.21                  | 27.91 | 25.57                   | 26.64 |
| AB                             | 28.77            | 28.59 | 31.98 | 30.12                  | 26.30 | 26.73                   | 30.98 |
| AN                             | 8.31             | 6.78  | 0.39  | 8.95                   | 0.35  | 3.96                    | 0.26  |
| C                              | 4.11             | 2.50  | 2.57  | 2.70                   | 4.17  | 3.32                    | 3.55  |
| EN                             | 4.65             | 3.69  | 2.00  | 4.75                   | 2.23  | 3.22                    | 2.17  |
| IL                             | 0.24             | 0.19  | 0.08  | 0.17                   | 0.05  | 0.17                    | 0.12  |
| HM                             | 4.96             | 4.19  | 1.17  | 4.29                   | 1.71  | 3.21                    | 1.39  |
| RU                             | 0.58             | 0.43  | 0.00  | 0.56                   | 0.11  | 0.33                    | 0.06  |
| AP                             | 0.50             | 0.44  | 0.33  | 0.49                   | 0.42  | 0.50                    | 0.69  |
| A/CNK                          | 1.31             | 1.16  | 1.20  | 1.17                   | 1.52  | 1.24                    | 1.24  |
| TTDI                           | 76.66            | 81.78 | 93.38 | 78.09                  | 90.96 | 85.29                   | 91.77 |
| Col. Ind.                      | 9.83             | 8.07  | 3.33  | 9.21                   | 4.00  | 6.61                    | 3.67  |
| Trace Elements (ppm*)          |                  |       |       |                        |       |                         |       |
| Ba                             | 758              | 584   | 62    | 698                    | 802   | 406                     | 199   |
| Rb                             | 144              | 169   | 273   | 134                    | 142   | 198                     | 244   |
| Sr                             | 176              | 126   | 17    | 187                    | 79    | 95                      | 37    |
| Zr                             | 191              | 202   | 45    | 182                    | 54    | 138                     | 48    |
| Nb                             | 13               | 13    | 7     | 12                     | 6     | 11                      | 8     |
| V                              | 65               | 37    | 2     | 54                     | 11    | 29                      | 2     |
| Y                              | 34               | 42    | 24    | 29                     | 21    | 33                      | 19    |
| Ga                             | 21               | 18    | 17    | 22                     | 16    | 17                      | 16    |
| Cu                             | 19               | 4     | 7     | 6                      | 3     | 7                       | 0     |
| Zn                             | 78               | 61    | 33    | 86                     | 24    | 59                      | 26    |
| Hf                             | 6                | 7     | 2     | 6                      | 2     | 4                       | 1     |
| Ta                             | 1.1              | 1.2   | 1.7   | 1.0                    | 0.7   | 1.4                     | 1.8   |
| Sc                             | 12.4             | 9.8   | 3.0   | 10.4                   | 3.6   | 7.7                     | 2.7   |
| La                             | 36               | 35    | 4     | 36                     | 10    | 24                      | 7     |
| Th                             | 12.1             | 12.7  | 4.2   | 12.9                   | 5.3   | 10.1                    | 3.7   |
| U                              | 3.6              | 3.6   | 5.7   | 2.7                    | 3.5   | 3.7                     | 4.1   |
| Li                             | 59               | 60    | 47    | 49                     | 14    | 75                      | 89    |
| F                              | 531              | 672   | 205   | 601                    | 230   | 624                     | 403   |
| As                             | 5.9              | 6.5   | 13.2  | 1.3                    | 94.6  | 5.6                     | 6.1   |
| Sn                             | 1                | 6     | 3     | 7                      | 10    | 8                       | 12    |
| W                              | 0                | 1     | 5     | 1                      | 1     | 2                       | 3     |

Table 5.1 Average major and trace element geochemistry and normative mineralogy of

| Pluton<br>Rock Type<br>% of Pluton<br>Samples | Scrag Lake (SGP) |       |       | Salmontail Lake (STP) |       |       |
|-----------------------------------------------|------------------|-------|-------|-----------------------|-------|-------|
|                                               | BGD              | BMG   | FGLMG | BGD                   | BMG   | FGLMG |
|                                               | 21.2             | 78.4  | 0.4   | 8.3                   | 91.2  | 0.5   |
|                                               | 23               | 21    | 22    | 3                     | 30    | 5     |
| SiO <sub>2</sub>                              | 67.13            | 68.27 | 73.98 | 68.96                 | 68.60 | 72.65 |
| Al <sub>2</sub> O <sub>3</sub>                | 15.08            | 15.03 | 14.18 | 14.70                 | 14.86 | 14.73 |
| Fe <sub>2</sub> O <sub>3</sub>                | 4.90             | 4.16  | 1.48  | 3.93                  | 3.97  | 1.29  |
| CaO                                           | 2.02             | 1.74  | 0.49  | 1.67                  | 1.46  | 0.44  |
| MgO                                           | 1.78             | 1.62  | 0.90  | 1.63                  | 1.52  | 0.93  |
| Na <sub>2</sub> O                             | 3.18             | 3.30  | 3.51  | 3.30                  | 3.44  | 3.61  |
| K <sub>2</sub> O                              | 3.73             | 4.02  | 4.73  | 3.78                  | 4.02  | 4.72  |
| TiO <sub>2</sub>                              | 0.72             | 0.60  | 0.15  | 0.59                  | 0.57  | 0.16  |
| P <sub>2</sub> O <sub>5</sub>                 | 0.21             | 0.21  | 0.20  | 0.19                  | 0.22  | 0.28  |
| MnO                                           | 0.09             | 0.08  | 0.05  | 0.08                  | 0.09  | 0.04  |
| H <sub>2</sub> O                              | 0.51             | 0.57  | 0.52  | 0.69                  | 0.61  | 0.60  |
| Q                                             | 28.30            | 28.39 | 33.71 | 30.15                 | 28.81 | 32.39 |
| OR                                            | 22.30            | 23.98 | 28.09 | 22.64                 | 24.06 | 28.22 |
| AB                                            | 27.23            | 28.23 | 29.77 | 28.25                 | 29.48 | 30.86 |
| AN                                            | 3.74             | 7.36  | 1.20  | 7.13                  | 5.85  | 0.48  |
| C                                             | 2.67             | 2.60  | 2.86  | 2.62                  | 2.77  | 3.55  |
| EN                                            | 4.48             | 4.08  | 2.24  | 4.12                  | 3.83  | 2.34  |
| IL                                            | 0.20             | 0.18  | 0.10  | 0.17                  | 0.18  | 0.08  |
| HM                                            | 4.96             | 4.20  | 1.48  | 3.98                  | 4.02  | 1.31  |
| RU                                            | 0.62             | 0.51  | 0.10  | 0.51                  | 0.47  | 0.12  |
| AP                                            | 0.50             | 0.48  | 0.46  | 0.44                  | 0.53  | 0.65  |
| A/CNK                                         | 1.17             | 1.17  | 1.21  | 1.17                  | 1.18  | 1.25  |
| TTDI                                          | 77.82            | 80.60 | 91.56 | 81.04                 | 82.35 | 91.46 |
| Col. Ind.                                     | 9.64             | 8.45  | 3.83  | 8.26                  | 8.03  | 3.73  |
| Ba                                            | 684              | 613   | 242   | 546                   | 525   | 402   |
| Rb                                            | 152              | 156   | 220   | 148                   | 165   | 205   |
| Sr                                            | 157              | 136   | 56    | 132                   | 123   | 52    |
| Zr                                            | 220              | 188   | 67    | 174                   | 181   | 71    |
| Nb                                            | 13               | 12    | 10    | 12                    | 12    | 9     |
| V                                             | 62               | 51    | 5     | 47                    | 42    | 5     |
| Y                                             | 37               | 35    | 23    | 31                    | 33    | 21    |
| Ga                                            | 19               | 18    | 17    | 19                    | 20    | 19    |
| Cu                                            | 7                | 3     | 1     | 5                     | 5     | 0     |
| Zn                                            | 75               | 65    | 37    | 73                    | 73    | 43    |
| Hf                                            | 7                | 6     | 2     | 6                     | 6     | 2     |
| Ta                                            | 1.3              | 1.3   | 2.0   | 1.2                   | 1.8   | 1.6   |
| Sc                                            | 12.0             | 9.6   | 3.1   | 9.3                   | 9.8   | 4.1   |
| La                                            | 37               | 30    | 11    | 32                    | 31    | 13    |
| Th                                            | 13.3             | 11.6  | 5.9   | 11.6                  | 11.7  | 7.3   |
| U                                             | 3.0              | 3.4   | 5.2   | 2.6                   | 3.6   | 5.5   |
| Li                                            | 71               | 57    | 43    | 70                    | 86    | 81    |
| F                                             | 759              | 581   | 335   | 583                   | 589   | 278   |
| As                                            | 8.1              | 5.6   | 15.9  | 4.2                   | 5.6   | 5.3   |
| Sn                                            | 4                | 3     | 7     | 4                     | 6     | 13    |
| W                                             | 1                | 0     | 4     | 1                     | 1     | 4     |

Table 5.2 Average major and trace element geochemistry and normative mineralogy of Stage II plutons

| Pluton<br>Rock Type<br>% of Pluton<br>Samples | Big Indian Lake (BIP) |       |       | Davis Lake (DLP) |       |       |       |       |
|-----------------------------------------------|-----------------------|-------|-------|------------------|-------|-------|-------|-------|
|                                               | MBMG                  | CGLMG | FGLMG | BGD              | MBMG  | CGLMG | FGLMG | MLG   |
|                                               | 1.8                   | 81.4  | 16.8  | 1.3              | 0.6   | 93.9  | 3.6   | 0.5   |
|                                               | 2                     | 9     | 9     | 2                | 5     | 29    | 2     | 5     |
| SiO <sub>2</sub>                              | 72.16                 | 73.95 | 74.32 | 67.87            | 73.81 | 72.85 | 74.32 | 74.26 |
| Al <sub>2</sub> O <sub>3</sub>                | 14.34                 | 13.86 | 13.97 | 15.22            | 13.17 | 14.19 | 13.68 | 13.99 |
| Fe <sub>2</sub> O <sub>3</sub>                | 2.71                  | 1.52  | 1.08  | 4.45             | 2.12  | 1.97  | 1.71  | 1.99  |
| CaO                                           | 0.73                  | 0.46  | 0.30  | 1.59             | 0.60  | 0.74  | 0.39  | 0.29  |
| MgO                                           | 1.40                  | 0.97  | 0.83  | 1.83             | 1.03  | 0.98  | 0.81  | 0.79  |
| Na <sub>2</sub> O                             | 3.41                  | 3.49  | 3.44  | 3.32             | 3.54  | 3.57  | 3.38  | 3.13  |
| K <sub>2</sub> O                              | 4.61                  | 4.60  | 5.13  | 3.91             | 4.47  | 4.52  | 4.06  | 4.10  |
| TiO <sub>2</sub>                              | 0.36                  | 0.15  | 0.07  | 0.71             | 0.19  | 0.21  | 0.05  | 0.05  |
| P <sub>2</sub> O <sub>5</sub>                 | 0.15                  | 0.17  | 0.15  | 0.23             | 0.12  | 0.21  | 0.17  | 0.24  |
| MnO                                           | 0.09                  | 0.06  | 0.08  | 0.10             | 0.06  | 0.05  | 0.08  | 0.08  |
| H <sub>2</sub> O                              | 0.75                  | 0.68  | 0.49  | 0.75             | 0.78  | 0.57  | 1.20  | 1.08  |
| Q                                             | 31.51                 | 34.32 | 33.34 | 28.37            | 33.78 | 32.54 | 38.11 | 39.57 |
| OR                                            | 27.27                 | 27.44 | 30.53 | 23.29            | 26.72 | 26.89 | 24.35 | 24.49 |
| AB                                            | 28.83                 | 29.77 | 29.29 | 28.28            | 30.32 | 30.46 | 28.96 | 26.70 |
| AN                                            | 2.65                  | 1.18  | 0.64  | 6.45             | 2.21  | 2.31  | 0.83  | 0.13  |
| C                                             | 2.78                  | 2.72  | 2.53  | 3.22             | 1.72  | 2.60  | 3.48  | 4.41  |
| EN                                            | 3.48                  | 2.43  | 2.07  | 4.60             | 2.58  | 2.44  | 2.04  | 2.00  |
| IL                                            | 0.18                  | 0.12  | 0.11  | 0.21             | 0.13  | 0.10  | 0.09  | 0.10  |
| HM                                            | 2.71                  | 1.53  | 1.02  | 4.49             | 2.14  | 1.98  | 1.65  | 1.92  |
| RU                                            | 0.26                  | 0.08  | 0.01  | 0.60             | 0.12  | 0.16  | 0.00  | 0.00  |
| AP                                            | 0.34                  | 0.40  | 0.35  | 0.53             | 0.28  | 0.50  | 0.40  | 0.55  |
| A/CNK                                         | 1.21                  | 1.20  | 1.19  | 1.22             | 1.12  | 1.18  | 1.29  | 1.46  |
| TTDI                                          | 87.60                 | 91.52 | 93.16 | 79.93            | 90.81 | 89.90 | 91.40 | 90.76 |
| Col. Ind.                                     | 6.37                  | 4.09  | 3.30  | 9.29             | 4.85  | 4.53  | 3.89  | 4.14  |
| Ba                                            | 403                   | 173   | 102   | 579              | 151   | 244   | 24    | 25    |
| Rb                                            | 190                   | 198   | 185   | 167              | 495   | 334   | 744   | 946   |
| Sr                                            | 96                    | 38    | 21    | 143              | 33    | 54    | 6     | 14    |
| Zr                                            | 125                   | 58    | 39    | 188              | 95    | 104   | 34    | 33    |
| Nb                                            | 10                    | 8     | 5     | 11               | 14    | 12    | 21    | 24    |
| V                                             | 22                    | 9     | 3     | 55               | 13    | 9     | 0     | 0     |
| Y                                             | 27                    | 17    | 16    | 31               | 59    | 38    | 60    | 64    |
| Ga                                            | 21                    | 18    | 19    | 18               | 20    | 19    | 24    | 27    |
| Cu                                            | 0                     | 0     | 4     | 10               | 13    | 2     | 7     | 143   |
| Zn                                            | 49                    | 36    | 30    | 67               | 40    | 43    | 53    | 104   |
| Hf                                            | 5                     | 2     | 1     | 5                | 2     | 3     | 0     | 0     |
| Ta                                            | 1.0                   | 1.6   | 0.8   | 1.2              | 3.6   | 2.4   | 8.3   | 9.8   |
| Sc                                            | 6.4                   | 3.3   | 2.7   | 9.2              | 3.9   | 3.1   | 2.5   | 2.5   |
| La                                            | 25                    | 9     | 5     | 28               | 16    | 17    | 6     | 3     |
| Th                                            | 12.0                  | 4.9   | 2.8   | 12.0             | 18.0  | 12.8  | 12.5  | 11.8  |
| U                                             | 3.9                   | 4.1   | 4.0   | 3.4              | 20.2  | 10.1  | 18.3  | 27.5  |
| Li                                            | 47                    | 47    | 26    | 69               | 136   | 103   | 237   | 329   |
| F                                             | 470                   | 311   | 120   | 600              | 2686  | 1042  | 4034  | 3900  |
| As                                            | 0.8                   | 2.2   | 1.2   | 1.5              | 1.9   | 2.2   | 0.0   | 2.3   |
| Sn                                            | 9                     | 9     | 9     | 6                | 19    | 13    | 27    | 204   |
| W                                             | 2                     | 1     | 1     | 0                | 26    | 3     | 63    | 19    |

Table 5.2 Average major and trace element geochemistry and normative mineralogy of Stage II plutons

| Pluton<br>Rock Type<br>% of Pluton<br>Samples | East Dalhousie (EDP) |       |       |       | Halifax (HP) |       |       |       |
|-----------------------------------------------|----------------------|-------|-------|-------|--------------|-------|-------|-------|
|                                               | MBMG                 | CGLMG | FGLMG | MLG   | BGD          | MP    | BMG   | MBMG  |
|                                               | 0                    | 0     | 0     | 0     | 4.1          | 0.1   | 12.6  | 33.3  |
|                                               | 6                    | 13    | 21    | 16    | 10           | 2     | 18    | 25    |
| SiO <sub>2</sub>                              | 72.50                | 73.20 | 73.65 | 73.58 | 67.73        | 68.94 | 70.24 | 71.07 |
| Al <sub>2</sub> O <sub>3</sub>                | 14.53                | 14.38 | 14.41 | 14.62 | 15.55        | 14.75 | 14.88 | 14.63 |
| Fe <sub>2</sub> O <sub>3</sub>                | 1.77                 | 1.71  | 1.37  | 1.19  | 4.10         | 3.24  | 3.13  | 2.83  |
| CaO                                           | 0.56                 | 0.49  | 0.38  | 0.45  | 1.75         | 1.77  | 1.20  | 1.03  |
| MgO                                           | 0.98                 | 0.88  | 0.84  | 0.74  | 1.67         | 2.86  | 1.39  | 1.23  |
| Na <sub>2</sub> O                             | 3.49                 | 3.36  | 3.45  | 3.87  | 3.67         | 4.10  | 3.44  | 3.56  |
| K <sub>2</sub> O                              | 5.07                 | 4.82  | 4.45  | 3.96  | 3.98         | 3.82  | 4.51  | 4.47  |
| TiO <sub>2</sub>                              | 0.21                 | 0.17  | 0.12  | 0.05  | 0.58         | 0.43  | 0.41  | 0.39  |
| P <sub>2</sub> O <sub>5</sub>                 | 0.25                 | 0.25  | 0.31  | 0.47  | 0.19         | 0.20  | 0.18  | 0.25  |
| MnO                                           | 0.04                 | 0.04  | 0.04  | 0.04  | 0.09         | 0.08  | 0.07  | 0.06  |
| H <sub>2</sub> O                              | 0.55                 | 0.52  | 0.64  | 0.80  | 0.67         | 0.60  | 0.62  | 0.65  |
| Q                                             | 31.01                | 33.75 | 35.50 | 35.09 | 25.65        | 23.11 | 28.95 | 30.06 |
| OR                                            | 30.16                | 28.73 | 26.54 | 23.65 | 23.70        | 22.51 | 26.82 | 26.58 |
| AB                                            | 29.73                | 28.59 | 29.48 | 33.01 | 31.22        | 34.57 | 29.29 | 30.23 |
| AN                                            | 1.13                 | 0.86  | 0.23  | 0.00  | 7.48         | 7.19  | 4.83  | 3.46  |
| C                                             | 2.90                 | 3.34  | 3.87  | 3.99  | 2.49         | 1.23  | 2.59  | 2.69  |
| EN                                            | 2.45                 | 2.20  | 2.11  | 1.86  | 4.19         | 7.02  | 3.48  | 3.08  |
| IL                                            | 0.10                 | 0.09  | 0.09  | 0.06  | 0.19         | 0.16  | 0.15  | 0.13  |
| HM                                            | 1.78                 | 1.72  | 1.38  | 1.18  | 4.13         | 3.24  | 3.15  | 2.85  |
| RU                                            | 0.16                 | 0.12  | 0.08  | 0.02  | 0.49         | 0.34  | 0.33  | 0.32  |
| AP                                            | 0.59                 | 0.59  | 0.72  | 1.11  | 0.45         | 0.46  | 0.41  | 0.59  |
| A/CNK                                         | 1.19                 | 1.24  | 1.29  | 1.28  | 1.15         | 1.06  | 1.17  | 1.17  |
| TTDI                                          | 90.90                | 91.07 | 91.53 | 91.76 | 80.57        | 80.18 | 85.06 | 86.87 |
| Col. Ind.                                     | 4.33                 | 4.01  | 3.58  | 3.12  | 8.51         | 10.60 | 6.79  | 6.06  |
| Ba                                            | 307                  | 170   | 129   | 33    | 588          | 354   | 469   | 360   |
| Rb                                            | 297                  | 322   | 377   | 557   | 164          | 201   | 198   | 242   |
| Sr                                            | 54                   | 36    | 27    | 13    | 171          | 120   | 122   | 92    |
| Zr                                            | 99                   | 75    | 55    | 32    | 177          | 119   | 140   | 132   |
| Nb                                            | 14                   | 12    | 13    | 22    | 12           | 11    | 11    | 14    |
| V                                             | 6                    | 6     | 3     | 2     | 44           | 35    | 29    | 26    |
| Y                                             | 23                   | 23    | 21    | 26    | 32           | 22    | 30    | 24    |
| Ga                                            | 19                   | 20    | 21    | 27    | 22           | 20    | 21    | 22    |
| Cu                                            | 1                    | 0     | 1     | 1     | 1            | 2     | 2     | 3     |
| Zn                                            | 51                   | 54    | 48    | 50    | 71           | 59    | 66    | 65    |
| Hf                                            | 3                    | 3     | 1     | 1     | 6            | 3     | 4     | 4     |
| Ta                                            | 2.1                  | 2.1   | 3.2   | 4.0   | 1.1          | 1.4   | 1.2   | 1.7   |
| Sc                                            | 3.0                  | 2.5   | 2.8   | 2.6   | 9.4          | 7.2   | 6.7   | 5.8   |
| La                                            | 20                   | 13    | 8     | 4     | 34           | 22    | 27    | 24    |
| Th                                            | 13.8                 | 9.8   | 5.3   | 3.4   | 12.3         | 10.0  | 11.6  | 11.2  |
| U                                             | 4.7                  | 4.7   | 4.9   | 3.1   | 3.0          | 4.0   | 3.6   | 4.3   |
| Li                                            | 96                   | 113   | 153   | 149   | 76           | 95    | 88    | 93    |
| F                                             | 1045                 | 1223  | 1134  | 1953  | 646          | 650   | 638   | 710   |
| As                                            | 4.1                  | 2.6   | 6.1   | 2.7   | 4.6          | 4.3   | 2.3   | 2.9   |
| Sn                                            | 11                   | 13    | 22    | 25    | 5            | 14    | 7     | 9     |
| W                                             | 3                    | 2     | 5     | 6     | 1            | 1     | 1     | 1     |



Table 5.2 Average major and trace element geochemistry and normative mineralogy of Stage II plutons

| Pluton<br>Rock Type<br>% of Pluton<br>Samples | Halifax (HP) Cont. |       | Kejimikujik (KP)<br>MBMG | Morse Road (MRP) |       | New Ross (NRP) |       |
|-----------------------------------------------|--------------------|-------|--------------------------|------------------|-------|----------------|-------|
|                                               | CGLMG              | FGLMG |                          | CGLMG            | FGLMG | MBMG           | CGLMG |
|                                               | 37.6               | 12.3  |                          | 0                | 0     | 11.6           | 59.3  |
|                                               | 24                 | 27    |                          | 3                | 2     | 5              | 27    |
| SiO <sub>2</sub>                              | 72.85              | 74.29 | 69.90                    | 71.95            | 72.94 | 72.27          | 73.57 |
| Al <sub>2</sub> O <sub>3</sub>                | 14.35              | 14.20 | 15.15                    | 15.08            | 14.40 | 14.43          | 14.05 |
| Fe <sub>2</sub> O <sub>3</sub>                | 2.04               | 1.59  | 3.48                     | 2.00             | 1.90  | 2.22           | 1.84  |
| CaO                                           | 0.68               | 0.42  | 0.94                     | 0.66             | 0.70  | 0.70           | 0.56  |
| MgO                                           | 0.88               | 0.73  | 1.49                     | 1.09             | 1.23  | 1.18           | 0.95  |
| Na <sub>2</sub> O                             | 3.46               | 3.47  | 3.09                     | 3.15             | 3.25  | 3.60           | 3.39  |
| K <sub>2</sub> O                              | 4.64               | 4.38  | 4.29                     | 5.22             | 4.97  | 4.69           | 4.64  |
| TiO <sub>2</sub>                              | 0.20               | 0.13  | 0.46                     | 0.28             | 0.25  | 0.30           | 0.19  |
| P <sub>2</sub> O <sub>5</sub>                 | 0.22               | 0.24  | 0.24                     | 0.21             | 0.17  | 0.27           | 0.24  |
| MnO                                           | 0.06               | 0.05  | 0.09                     | 0.04             | 0.05  | 0.05           | 0.05  |
| H <sub>2</sub> O                              | 0.57               | 0.72  | 0.83                     | 0.57             | 0.55  | 0.55           | 0.50  |
| Q                                             | 33.00              | 36.15 | 32.22                    | 31.31            | 32.25 | 30.97          | 34.29 |
| OR                                            | 27.62              | 26.03 | 25.58                    | 30.95            | 29.42 | 27.81          | 27.57 |
| AB                                            | 29.49              | 29.50 | 26.37                    | 26.71            | 27.51 | 30.56          | 28.85 |
| AN                                            | 1.92               | 0.59  | 3.16                     | 1.92             | 2.37  | 1.69           | 1.27  |
| C                                             | 2.95               | 3.55  | 4.32                     | 3.57             | 2.82  | 2.81           | 3.00  |
| EN                                            | 2.21               | 1.83  | 3.74                     | 2.71             | 3.06  | 2.95           | 2.37  |
| IL                                            | 0.12               | 0.11  | 0.20                     | 0.10             | 0.10  | 0.10           | 0.10  |
| HM                                            | 2.05               | 1.59  | 3.51                     | 2.01             | 1.90  | 2.22           | 1.85  |
| RU                                            | 0.14               | 0.07  | 0.36                     | 0.23             | 0.20  | 0.25           | 0.14  |
| AP                                            | 0.51               | 0.57  | 0.55                     | 0.49             | 0.40  | 0.64           | 0.56  |
| A/CNK                                         | 1.20               | 1.27  | 1.33                     | 1.26             | 1.20  | 1.18           | 1.21  |
| TTDI                                          | 90.10              | 91.68 | 84.17                    | 88.98            | 89.18 | 89.34          | 90.72 |
| Col. Ind.                                     | 4.38               | 3.53  | 7.44                     | 4.82             | 5.05  | 5.27           | 4.31  |
| Ba                                            | 199                | 101   | 556                      | 391              | 376   | 273            | 205   |
| Rb                                            | 278                | 329   | 196                      | 268              | 217   | 312            | 311   |
| Sr                                            | 55                 | 28    | 108                      | 79               | 80    | 58             | 48    |
| Zr                                            | 84                 | 59    | 148                      | 117              | 105   | 126            | 83    |
| Nb                                            | 11                 | 11    | 10                       | 14               | 11    | 14             | 12    |
| V                                             | 11                 | 7     | 41                       | 11               | 15    | 16             | 9     |
| Y                                             | 23                 | 19    | 27                       | 23               | 24    | 24             | 25    |
| Ga                                            | 22                 | 21    | 17                       | 19               | 16    | 20             | 19    |
| Cu                                            | 0                  | 1     | 0                        | 0                | 0     | 0              | 1     |
| Zn                                            | 51                 | 47    | 58                       | 55               | 43    | 62             | 51    |
| Hf                                            | 3                  | 2     | 4                        | 4                | 4     | 3              | 3     |
| Ta                                            | 1.9                | 2.4   | 1.7                      | 1.6              | 1.3   | 1.9            | 2.1   |
| Sc                                            | 4.0                | 3.2   | 6.3                      | 3.4              | 3.4   | 3.9            | 3.4   |
| La                                            | 15                 | 8     | 27                       | 27               | 24    | 22             | 15    |
| Th                                            | 8.2                | 5.1   | 11.0                     | 16.3             | 13.0  | 17.9           | 9.8   |
| U                                             | 5.8                | 8.8   | 4.8                      | 5.1              | 5.3   | 3.8            | 5.5   |
| Li                                            | 95                 | 108   | 76                       | 78               | 79    | 105            | 107   |
| F                                             | 763                | 759   | 534                      | 562              | 479   | 1495           | 1135  |
| As                                            | 3.7                | 5.5   | 1.6                      | 5.7              | 4.2   | 71.9           | 2.4   |
| Sn                                            | 12                 | 20    | 3                        | 7                | 4     | 11             | 14    |
| W                                             | 2                  | 6     | 1                        | 0                | 0     | 7              | 3     |

Table 5.2 Cont.

| Pluton<br>Rock Type<br>% of Pluton<br>Samples | NRP Cont |       | West Dalhousie (WD) |       |
|-----------------------------------------------|----------|-------|---------------------|-------|
|                                               | FGLMG    | MLG   | CGLMG               | FGLMG |
|                                               | 27.6     | 1.5   | 99.5                | 0.5   |
|                                               | 41       | 7     | 11                  | 3     |
| SiO <sub>2</sub>                              | 74.19    | 73.77 | 72.44               | 73.66 |
| Al <sub>2</sub> O <sub>3</sub>                | 14.16    | 14.50 | 14.49               | 14.45 |
| Fe <sub>2</sub> O <sub>3</sub>                | 1.30     | 1.28  | 2.00                | 1.35  |
| CaO                                           | 0.39     | 0.29  | 0.65                | 0.42  |
| MgO                                           | 0.86     | 0.72  | 1.07                | 0.94  |
| Na <sub>2</sub> O                             | 3.61     | 3.77  | 3.15                | 3.17  |
| K <sub>2</sub> O                              | 4.45     | 4.15  | 4.97                | 4.60  |
| TiO <sub>2</sub>                              | 0.11     | 0.07  | 0.27                | 0.16  |
| P <sub>2</sub> O <sub>5</sub>                 | 0.27     | 0.40  | 0.21                | 0.26  |
| MnO                                           | 0.04     | 0.03  | 0.04                | 0.03  |
| H <sub>2</sub> O                              | 0.57     | 0.63  | 0.62                | 0.67  |
| Q                                             | 34.83    | 35.17 | 32.90               | 36.36 |
| OR                                            | 26.49    | 24.73 | 29.61               | 27.45 |
| AB                                            | 30.75    | 32.13 | 26.84               | 27.11 |
| AN                                            | 0.42     | 0.00  | 1.90                | 0.42  |
| C                                             | 3.25     | 3.84  | 3.26                | 4.13  |
| EN                                            | 2.17     | 1.80  | 2.67                | 2.36  |
| IL                                            | 0.09     | 0.07  | 0.10                | 0.07  |
| HM                                            | 1.31     | 1.29  | 2.01                | 1.36  |
| RU                                            | 0.07     | 0.04  | 0.23                | 0.13  |
| AP                                            | 0.63     | 0.94  | 0.48                | 0.62  |
| A/CNK                                         | 1.24     | 1.30  | 1.23                | 1.32  |
| TTDI                                          | 92.07    | 92.03 | 89.36               | 90.91 |
| Col. Ind.                                     | 3.56     | 3.16  | 4.78                | 3.79  |
| Ba                                            | 116      | 39    | 364                 | 158   |
| Rb                                            | 356      | 785   | 251                 | 292   |
| Sr                                            | 25       | 18    | 67                  | 35    |
| Zr                                            | 53       | 44    | 107                 | 56    |
| Nb                                            | 12       | 27    | 12                  | 14    |
| V                                             | 2        | 2     | 12                  | 5     |
| Y                                             | 23       | 33    | 21                  | 20    |
| Ga                                            | 21       | 28    | 18                  | 19    |
| Cu                                            | 3        | 0     | 0                   | 0     |
| Zn                                            | 43       | 71    | 52                  | 46    |
| Hf                                            | 2        | 2     | 3                   | 1     |
| Ta                                            | 2.4      | 6.3   | 1.7                 | 3.1   |
| Sc                                            | 3.1      | 2.1   | 3.2                 | 2.1   |
| La                                            | 8        | 4     | 27                  | 13    |
| Th                                            | 5.7      | 6.2   | 17.0                | 8.8   |
| U                                             | 9.1      | 4.5   | 5.0                 | 8.7   |
| Li                                            | 93       | 410   | 80                  | 98    |
| F                                             | 1161     | 3884  | 638                 | 554   |
| As                                            | 6.8      | 1.5   | 5.7                 | 8.2   |
| Sn                                            | 18       | 34    | 6                   | 11    |
| W                                             | 6        | 10    | 1                   | 3     |

The sequence biotite granodiorite ( $\pm$  mafic porphyry) – biotite monzogranite – muscovite-biotite monzogranite – coarse-grained leucomonzogranite – fine-grained leucomonzogranite – muscovite leucogranite in both Stage I and II plutons is marked by systematic decreases in  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$  and  $\text{CaO}$  with increasing  $\text{SiO}_2$ .  $\text{Al}_2\text{O}_3$  also decreases with increasing  $\text{SiO}_2$  in most plutons with the exception of the Little Round Lake and Salmon Lake Stage I plutons where  $\text{Al}_2\text{O}_3$  levels are roughly constant throughout.  $\text{MnO}$  values generally show limited decrease with increasing  $\text{SiO}_2$ . In contrast the large variation in  $\text{MnO}$  values in the Cloud Lake pluton, particularly in biotite-rich mafic porphyry and dyke rocks, and in the fine-grained leucomonzogranite of the Big Indian Lake pluton, are for samples that contain Mn-rich garnet. In general  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  do not show well-defined compositional trends for the main rock types in the Stage I and II plutons. However, it should be noted that some rocks do show enrichment or depletion in these elements that presumably reflect variable degrees of alteration. For example, The enrichment in  $\text{Na}_2\text{O}$  and concomitant depletion in  $\text{K}_2\text{O}$  in the muscovite leucogranite of the East Dalhousie pluton may reflect albitization with the "stripping" of  $\text{K}_2\text{O}$  by fluids.  $\text{P}_2\text{O}_5$  is mainly constant with increasing  $\text{SiO}_2$  for the majority of rocks in both Stage I and II plutons but shows strong enrichment in leucomonzogranite and leucogranite in several Stage II plutons.

The sequence biotite granodiorite – muscovite leucogranite is also marked by decreases in normative anorthite, enstatite, ilmenite, hematite, rutile and colour index and several "compatible" trace elements (i.e. Ba, Sr, Zr, V, Hf, Sc and La) and increases in normative quartz, A/CNK and Thornton-Tuttle differentiation index and several "incompatible" trace elements (i.e. Rb, Ta, U, Li, F, Sn and W). Elements considered to be "compatible" are preferentially

partitioned into mineral phases during crystal fractionation and therefore are depleted in later-staged rocks. Conversely "incompatible" elements are preferentially partitioned into the melt and/or fluid phase during crystallization of a magma and will therefore become enriched in the more evolved, late-staged rocks. Some "incompatible" elements are incorporated into mineral phases, such as Rb in the phyllosilicate minerals, and some "compatible" elements may become enriched in some late-staged rocks, for example high  $P_2O_5$  in some leucogranite bodies. It should also be noted that some elements may change from compatible to incompatible behaviour during the crystallization history of a given granite body as a result of varying physico-chemical conditions. Thus, these terms are simply meant as guides to the overall behaviour of individual elements.

It is apparent from the major and trace element data and normative mineralogy (Tables 5.1, 5.2, Appendix A; Figures 5.2 and 5.3) that the amount of overall chemical variability differs between the various Stage I and Stage II plutons. For example the Stage II Halifax pluton, containing granodiorite, monzogranite and leucomonzogranite rock units, markedly contrasts with the Morse Road and Kejimikujik plutons that are dominated by compositionally restricted monzogranite and leucomonzogranite rocks. Similarly the Stage I Scrag Lake pluton, which displays a wide compositional range, is in marked contrast to the more compositionally restricted Little Round Lake pluton.

The chemical data also reveal compositional differences between the rock types in various plutons. For example, coarse-grained leucomonzogranite in the Davis Lake pluton has a much larger compositional range (e.g.  $SiO_2$  ca. 67-75 wt %), than the same rock type in the Halifax and West Dalhousie plutons (e.g.  $SiO_2$  ca. 70.5-74 wt %), New Ross pluton (e.g.  $SiO_2$  ca. 71.5-

75.5 wt %), and the Big Indian Lake pluton (e.g.  $\text{SiO}_2$  ca. 73-75.5 wt %).

Several major element "discriminating" diagrams have been developed specifically for intrusive rocks. Data for average rock types from Stage I and II plutons have been plotted on a multi-cationic plot (Debon and LeFort, 1983) and is shown in Figure 5.4. This plot classifies samples based on the relative proportions of the quartzo-feldspathic elements Si, K, Na and Ca. Only the most "primitive" samples of mafic porphyry and granodiorite from Stage I and II plutons, plot near the granodiorite field (#3) with most data being split between the "adamellite" field (i.e. monzogranite - #2) and "granite" (i.e. syenogranite - #1) fields. There is no clear relationship between the measured quartz-alkali feldspar-plagioclase determinations from Chapter 4, and the positions of the major rock types in Figure 5.4. For example the least evolved "granodiorite" from Stage I and II plutons and the most evolved leucogranite from the Stage II plutons plot in the "adamellite" field.

Debon and LeFort (1983) also developed a multi-cationic diagram that specifically classifies granitoid rocks into peraluminous versus metaluminous groups and estimates the proportions of biotite, muscovite and hornblende. Plots of the average rock-type compositions for Stage I and II plutons are given in Figures 5.5a and b. Unlike the results for Figure 5.4, there is a remarkable agreement between the measured and predicted modal mineralogy. Firstly, all rocks correctly plot in the peraluminous field. Secondly, only the mafic porphyry and some biotite granodiorite units plot in the "biotite only" field (#III), biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite and leucomonzogranite all plot in the "biotite > muscovite" field (#II). Only fine-grained leucomonzogranite and leucogranite plot in the "muscovite" field (#I). None of the samples plot in the "hornblende + biotite" field (#IV) which is in accord with the



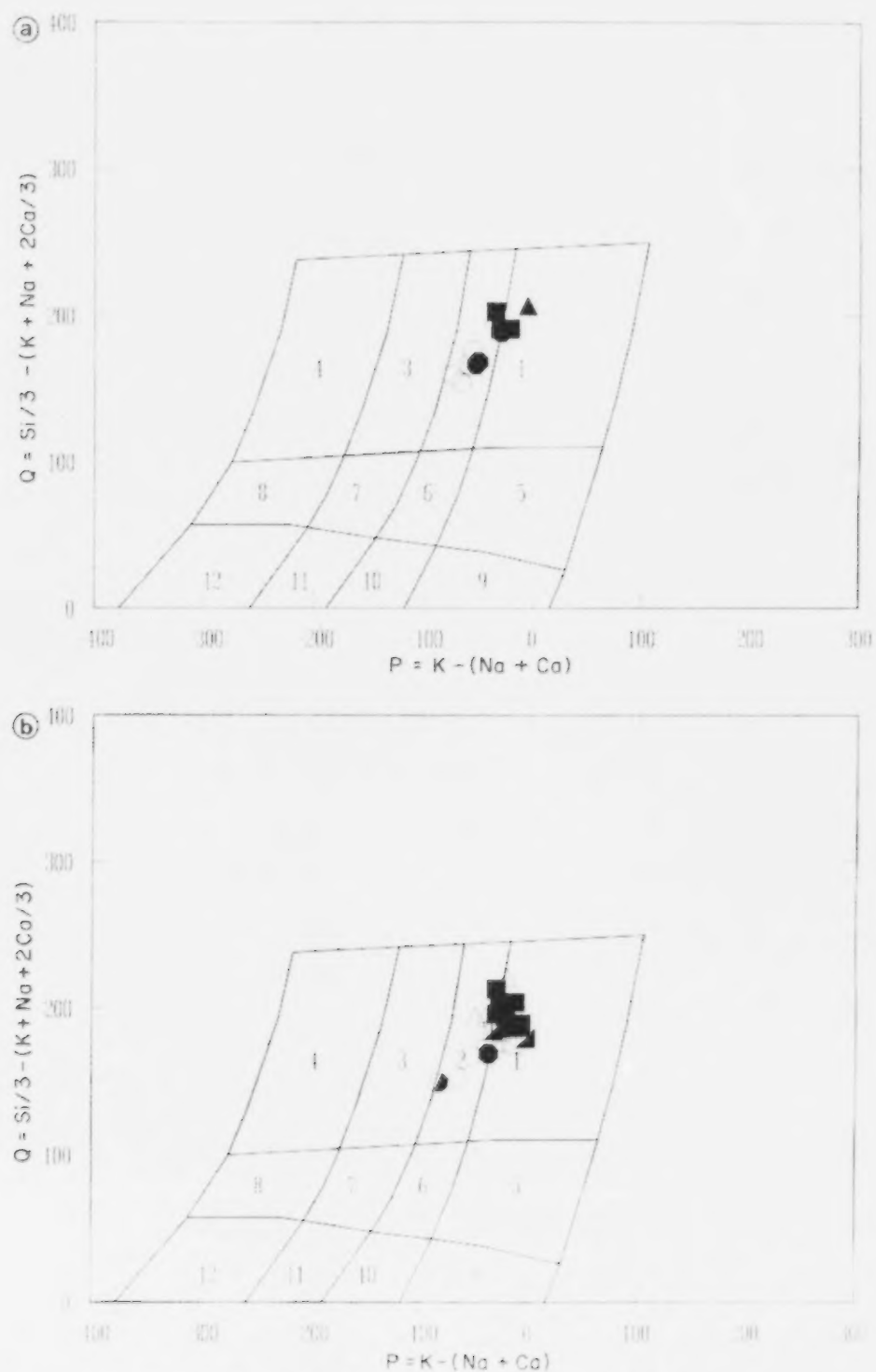


Figure 5.4 Multi-cationic plot (after Debon and LeFort, 1983) of average rock type for: a) Stage I plutons; b) Stage I plutons. Fields include #3 - granodiorite; #2 - monzogranite; #1 - syenogranite. See text for discussion.

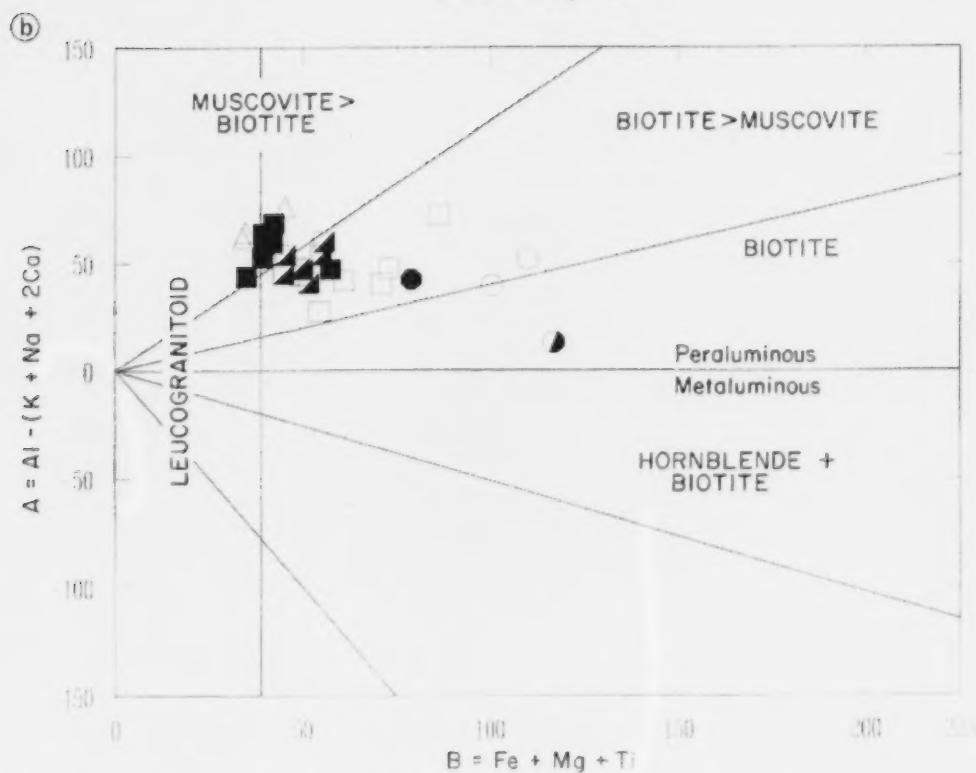
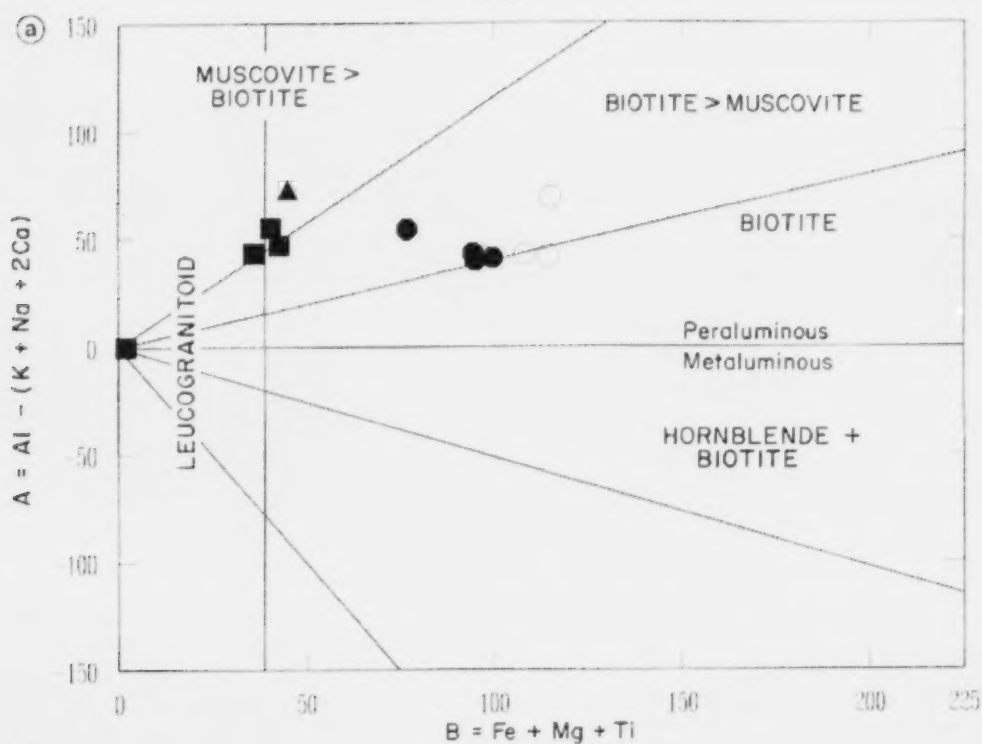


Figure 5.5 Multi-cationic plot (after Debon and LeFort, 1983) of average rock types for a) Stage I plutons; b) Stage II plutons. Note that all rocks plot in the peraluminous fields. See text for discussion.

observed petrographic data. Finally, only two leucogranite and two fine-grained leucomonzogranite bodies plot in the "leucogranitoid" field which supports the field observations from this study.

Middlemost (1985) presented a classification scheme for igneous rocks that was based on the proportions of  $\text{SiO}_2$  versus  $\text{Na}_2\text{O} + \text{K}_2\text{O}$ . Virtually all data from both Stage I and II plutons (Figs. 5.6a,b) plot in the "granite" (i.e. monzogranite and syenogranite fields; #6) with two granodiorite units correctly plotting in the granodiorite field (#11).

Ternary plots of normative quartz, alkali feldspar and plagioclase for Stage I and II plutons are given in Figures 5.7a and b (fields after LeMaitre, 1989). The granodiorite and mafic porphyry units from all plutons plot correctly in the granodiorite field. All other rock units plot in the monzogranite field with nearly complete overlap for all rock types. The chief reason for the lack of separation between these latter rock types is that normative albite is combined with normative anorthite (i.e. P) whereas the A apex is only made up of normative orthoclase. Therefore the shift toward syenogranite and even alkali feldspar granite that was shown in Figures 5.4 and 5.6 is absent in the LeMaitre (1989) plot. Streckeisen (1976) concluded that albitic plagioclase with  $\text{An}_{<5}$  should be combined with K-feldspar. Unfortunately normative programs do not provide an estimate of the relative proportions of albite with  $\text{An}_{<5}$  and  $\text{An}_{>5}$  which prohibits the generation of a normative equivalent to the Streckeisen (1976) diagram. Plots of the proportions of anorthite versus albite + orthoclase for the Scrag Lake Stage I and New Ross Stage II plutons have been prepared to further illustrate this problem and are displayed in Figures 5.8a and b. Lines of equal proportions (e.g. 1:2 An:Ab + Or) have also been included.

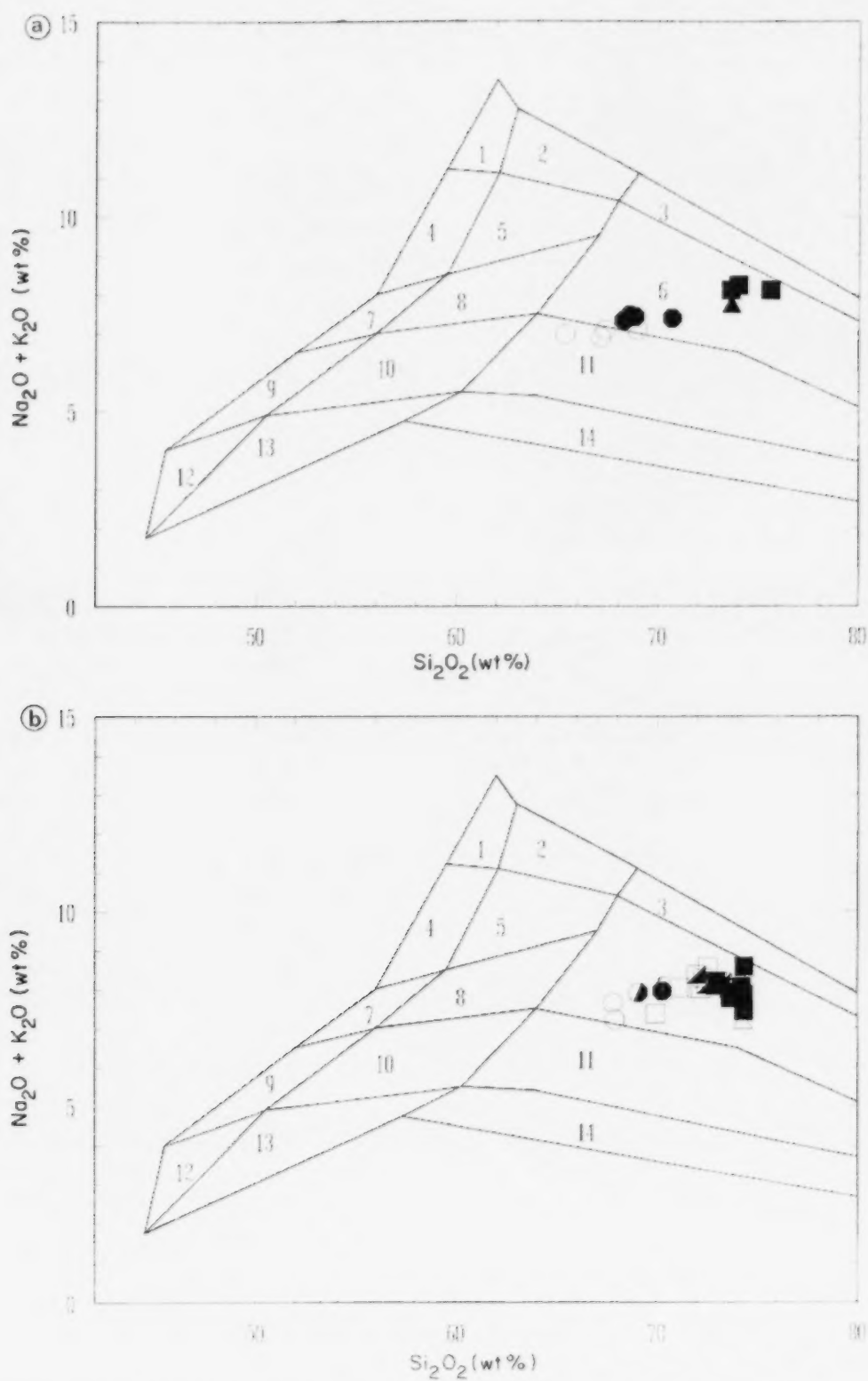


**Figure 5.6** Average rock data for Stage I and II plutons plotted on classification scheme of Middlemost (1985). a) Stage I plutons; b) Stage II plutons. See text for discussion.

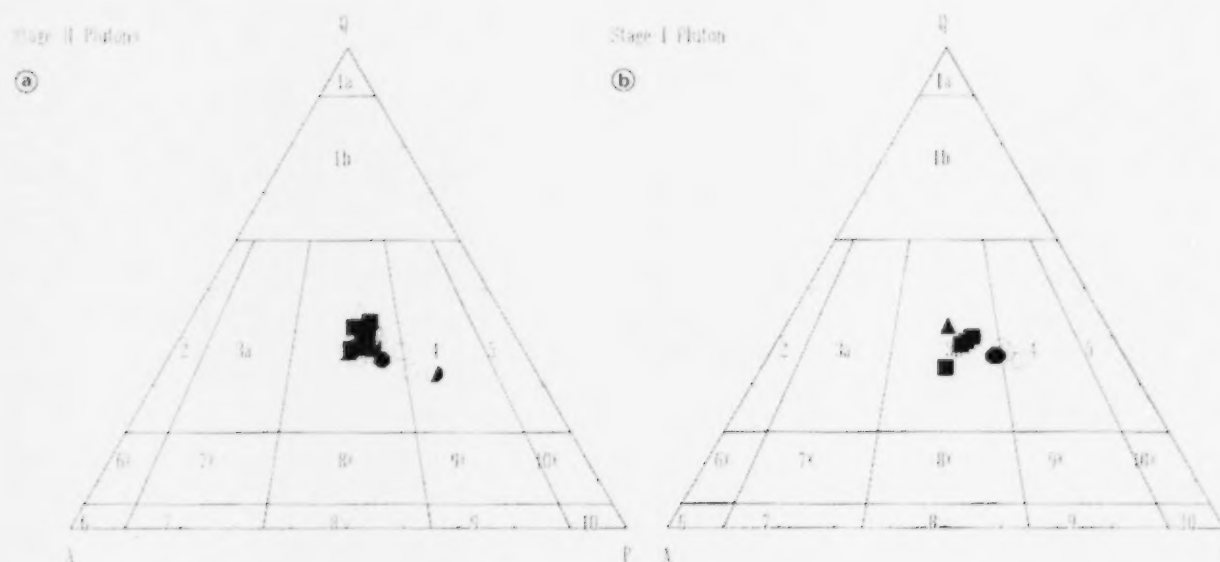


**Figure 5.7** Ternary plots of average CIPW normative data for Stage I and II plutons (fields after LeMaitre, 1989). a) Stage I plutons; b) Stage II plutons. See text for discussion.

When all albite is assigned to alkali feldspar, which clearly is not accurate in light of the petrographic information presented in Chapter 4, then granodiorite and biotite monzogranite from the Scrag Lake Stage I pluton plot in the syenogranite field (Fig 5.8a). Fine grained leucomonzogranite from this pluton and all samples from the New Ross pluton plot in the alkali feldspar field. Clearly the amount of shift toward alkali feldspar granite compositions is beyond what is predicted from the observed mineralogy. Therefore accurate designation of rock types for the batholith on the basis of normative mineralogy is not possible using available classification schemes. Proper classification will only be possible if the relative proportion of albite with  $An_{<5}$  and  $An_{>5}$  can be determined.

### 5.2.2 Chemical Zoning in Stage I and II Plutons

Most Stage I and II plutons are compositionally zoned with individual plutons displaying normal, reverse or normal & reverse zoning (MacDonald and Horne, 1988; Horne et al., 1989;

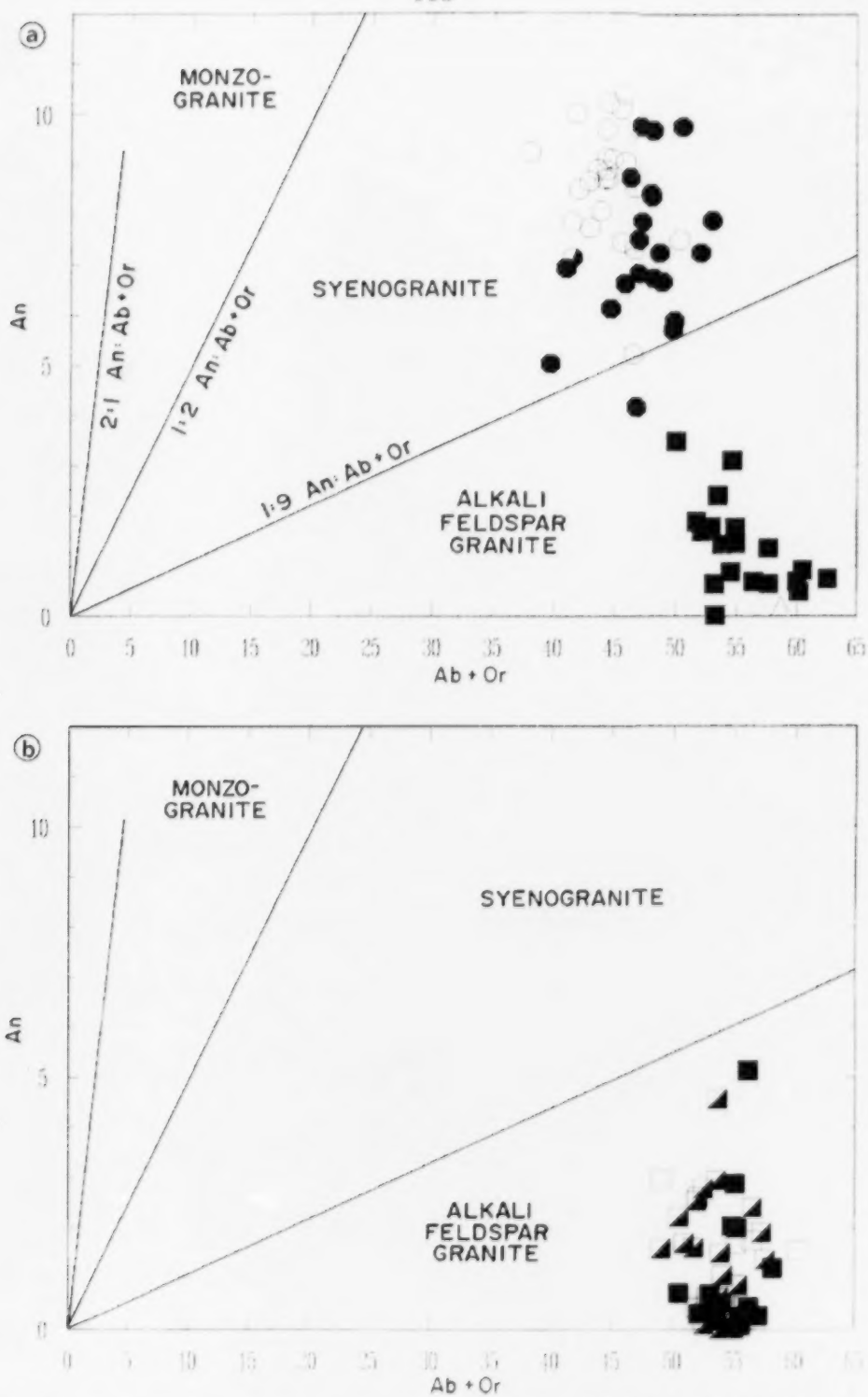


**Figure 5.8** Binary plots of normative anorthite (An) versus albite (Ab) + orthoclase (Or) for total data sets from: a) Scrag Lake Stage I pluton; and b) New Ross Stage II pluton. See text for discussion.



MacDonald et al., 1992). Normal zoning consists of plutons with least "evolved" compositions at or near the pluton margins and most "evolved" rock compositions in pluton cores. Reverse zoning, as the name implies, consists of more evolved margins and less evolved cores. The following section outlines a few examples of compositional zoning patterns from both Stage I and II plutons.

The Salmontail Lake Pluton displays the most consistent and symmetrical compositional zoning of the five Stage I plutons, as shown in Figures 5.9a to c. Concentrations of the "compatible" elements Sr and Zr are clearly highest along the pluton margins ( $> 140$  ppm Sr and  $> 210$  ppm Zr) and lowest ( $< 100$  ppm Sr and  $< 150$  ppm Zr) in two regions of the pluton core. Conversely the highest concentrations of the "incompatible" element Rb are generally lowest along the pluton margins ( $< 140$ - $160$  ppm) with highest values predominating the core of the pluton ( $> 180$  ppm). These patterns, and indeed the trends for most major and trace elements, are consistent with normal zoning as defined above. It should be noted that the most evolved rocks of the Salmontail Lake pluton, the Gold River fine-grained leucomonzogranite bodies, are situated in the most evolved portion of the pluton. O'Reilly (1992) has noted spatial association, and has proposed genetic relationships, between the New Ross Manganese Mines and the Gold River leucomonzogranite bodies. The positioning of mineral deposit and leucomonzogranite in the most evolved part of the large biotite monzogranite unit in the core of the Salmontail Lake pluton may be merely coincidental, but more likely indicates some degree of genetic association.

The Davis Lake Stage II Pluton has normal compositional zoning as shown in Figure 5.10a to f). The highest values of K/Rb ( $> 200$ ), which as stated above is a dependable indicator

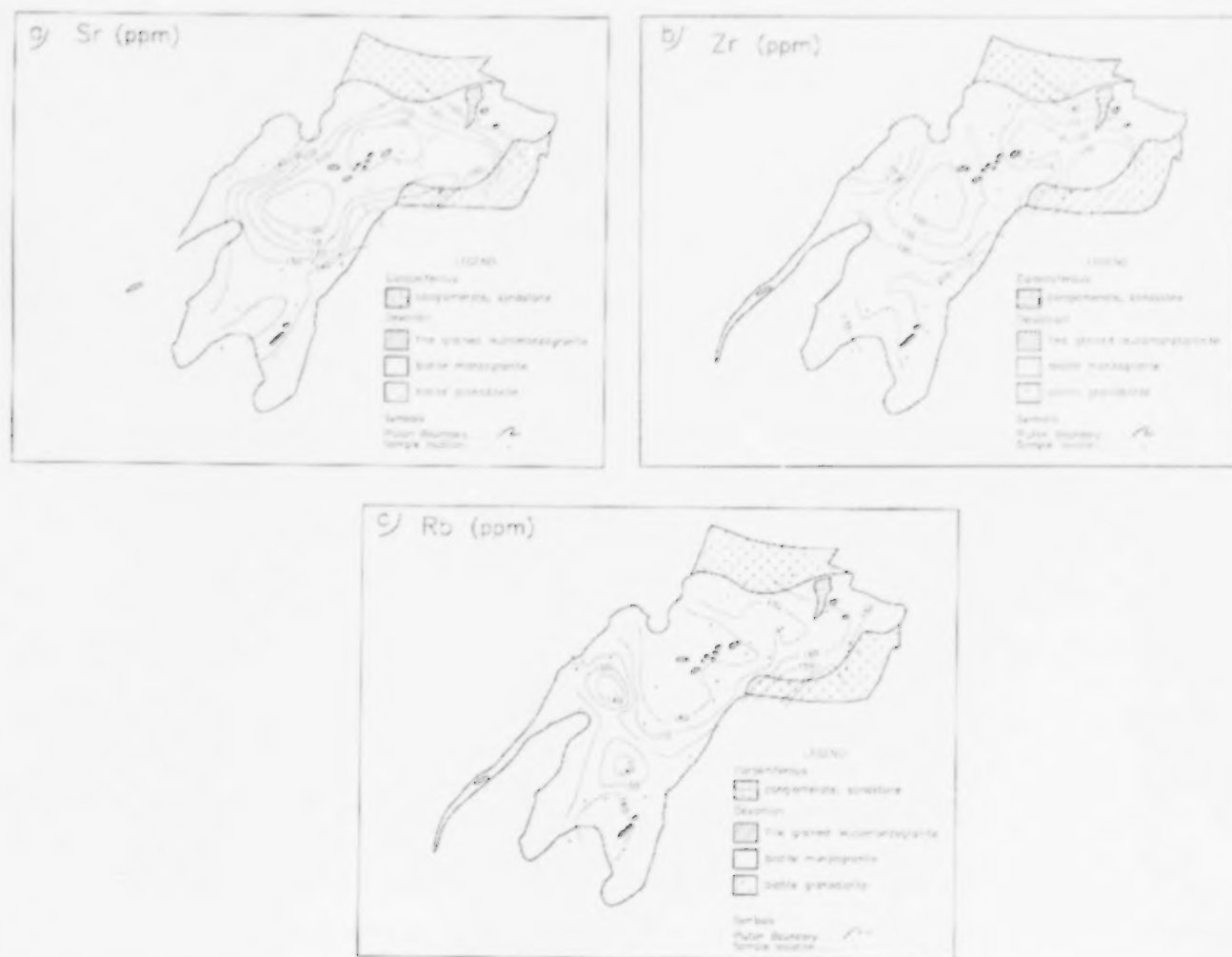


**Figure 5.9** Lithogeochemical contour plots for biotite monzogranite and biotite granodiorite from the Stage I Salmontail Lake Pluton. See text for discussion.



**Figure 5.10** Lithochemical contour plots for coarse-grained leucomonzogranite and biotite monzogranite from the Stage II Davis Lake Pluton. See text for discussion.

of the degree of differentiation, are for samples located along the northern and southeastern margins of the pluton. There is a progressive decrease in K/Rb toward the southwestern extension of the pluton where the lowest values (50-100) predominate. This transition from northern margin to the East Kemptville area is also marked by a decrease in most "compatible" elements (e.g. Zr) and increase in most "incompatible" elements (e.g. Rb, F, Sn). It is worthy of note that the East Kemptville leucogranite, and Sn deposit, resides in the most evolved part of the pluton, much like the Gold River leucomonzogranite bodies in the Salmontail pluton. In fact, Chatterjee and MacDonald (1991) successfully established a genetic link between the coarse-grained leucomonzogranite, the muscovite-topaz leucogranite and greisens from the East Kemptville Sn deposit using rare earth element geochemistry. Therefore it appears that there may be a causal relationship between the processes that generated regional-scale compositional zoning in plutons and the formation of mineral deposits. Kontak (1994) has also proposed that the East Kemptville deposit was formed by prolonged fractionation of the Davis Lake Pluton.

The Halifax Pluton is the best example of normal and reverse zoning in a Stage II pluton. Contour plots of Zr and Rb and a 3-dimensional perspective plot of Rb/Zr for data from the Halifax Pluton are presented in Figure 5.11a to c respectively. The western part of the pluton displays very systematic normal zoning with high Zr ( $> 200$  ppm) and low Rb ( $< 180$  ppm) and Rb/Zr in the granodiorite and biotite monzogranite along the margin to low Zr ( $< 80$  ppm) and high Rb ( $> 320$  ppm) and Rb/Zr in the core regions. In contrast the eastern portion of the pluton displays normal compositional zoning near the margin, as developed to the west, but has a reversely zoned core. The reader is referred to MacDonald and Horne (1988) for a detailed discussion of possible mechanisms for development of the observed zoning features. In simplistic

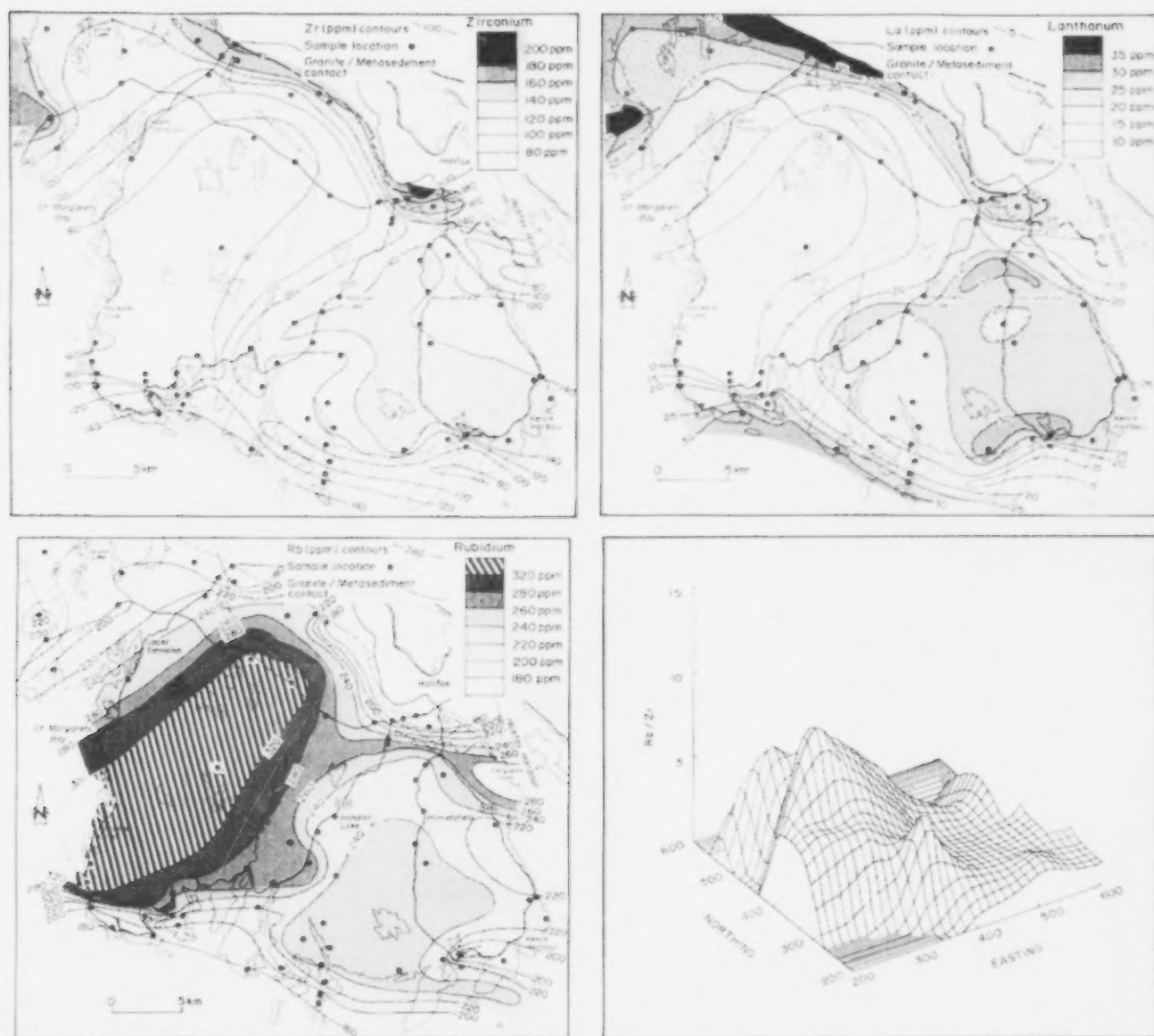


**Figure 5.11** Lithogeochemical contour plots and 3-Dimensional plot for biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite and coarse-grained leucomonzogranite from the Stage II Halifax Pluton. See text for discussion.

terms, MacDonald and Horne (1988) concluded that the zoning was formed by a combination of sidewall fractional crystallization along "cool" metasedimentary chamber walls, coupled with the development of vertical stratification, and subsequent upwelling of magma within a central

magma chamber.

The presence of both normal and reverse zoning in the sundry plutons of the batholith requires that zoning is not simply formed by static *in situ* fractional crystallization from margin to core of plutons because this process should only result in normally zoning. A comprehensive discussion of the various processes responsible for formation of zoning is beyond the scope of this report.



### 5.2.3 Comparison of Various Stage I & II Plutons

The above data indicate that the five Stage I and eight Stage II plutons have broadly similar chemical characteristics. Despite these overall similarities it is possible to distinguish among individual Stage I and II plutons. For example, binary element plots of  $\text{TiO}_2$  versus Zr and Ta versus F have been prepared for the Big Indian Lake and New Ross Stage II plutons (fig. 5.12a to d).  $\text{TiO}_2$  and Zr are very strongly correlated in both plutons ( $R=+0.98$  and  $+0.97$ , respectively). However, the overall concentrations of these elements, and the slopes of regression lines, vary between the two plutons (Fig. 5.12a,b). The respective concentrations and distribution of Ta and F also vary between the two plutons, as displayed in Figures 5.12c and d.

Much of the chemical differences between individual plutons are more subtle than those shown in Figure 5.12 and are very difficult to recognize using conventional bivariate or ternary elemental plots. Smith (1979) used multivariate statistical techniques to separate several Stage II plutons in the SMB. An evaluation of his data in light of recent mapping indicates that his sample sets consisted of a combination of Stage I and II plutons and therefore are not considered to present an accurate depiction of the chemistry of Stage II plutons.

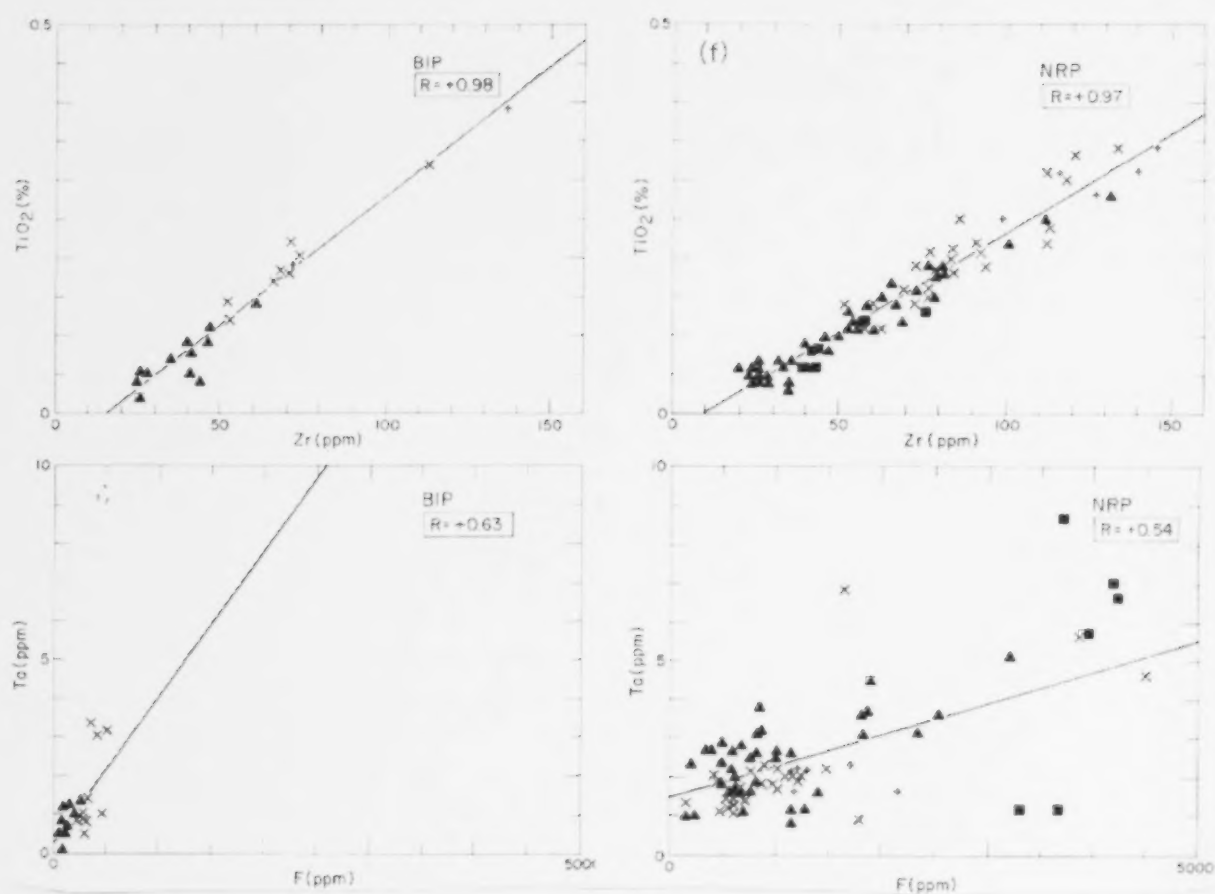


Figure 5.12 Bivariate plots for the Big Indian Lake and New Ross Stage II plutons. See text for discussion.

Horne et al. (1989) recognized chemical differences among biotite granodiorite and biotite monzogranite bodies from several Stage I plutons using multi-variate discriminant function analysis. They used a suite of high field strength elements ( $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ , Zr, Hf and Y) and concluded that the compositional differences between the various plutons resulted from variations in the mineral chemistry of biotite and the varying proportions of the associated accessory minerals zircon and xenotime entrained within this biotite. It should be noted that while there was little overlap in discriminant function scores between the various Stage I plutons, the within-group

variance generally exceeded the between-group separation. Therefore, one of the main mathematical criteria for reliable discrimination was not satisfied. It is possible that chemical distinctions between the various plutons might be successfully recognized (i.e. satisfying all mathematical criteria) by using step-wise multiple discrimination as noted by Chatterjee and Strong (1984) in their study of metasomatized uraniferous rocks in the batholith.

MacDonald et al. (1992) separated coarse-grained leucomonzogranite samples from six of the Stage II plutons including Davis Lake, West Dalhousie, East Dalhousie, New Ross, Big Indian Lake and Halifax. They then applied the same multi-variate techniques and suite of elements as Horne et al. (1989) to determine if the Stage II plutons could be discriminated. Their results indicate that samples from four of the plutons (Davis Lake, West Dalhousie, Big Indian Lake, and Halifax) could be correctly assigned to their respective bodies with a 70-85 % success rate, with the same mathematical restrictions as noted above. Conversely, the success rate for samples from the New Ross and East Dalhousie plutons was less convincing at only a 25 % success rate. Samples from these plutons were commonly misclassified as belonging to the other pluton or, to a lesser extent, to one of the above plutons suggesting a genetic relationship between these two plutons.

It is possible to distinguish between Stage II plutons using rare earth element (REE) data for a specific rock type. Sample suites from muscovite-biotite monzogranite units in the Halifax, New Ross, West Dalhousie, Kejimikujik and Davis Lake plutons were analyzed for REE (unpublished data A.K. Chatterjee, 1993). It should be stressed that most samples from muscovite-biotite monzogranite, with the exception of some rocks from the DLP, have  $K/Rb > 150$ , and thus are interpreted as "pristine magmatic" rocks. Plots of the REE analyses for the five units are plotted in Figure 5.13. Samples from each pluton show very cohesive geochemical behaviour with

consistent light (LREE) and heavy (HREE) fractionation patterns and  $\text{Eu}/\text{Eu}^*$ . In contrast, the REE patterns differ significantly among the various plutons. For example the rocks from the Halifax, Kejimikujik and New Ross plutons have fractionated patterns with similar ratios of LREE to HREE and similar Eu 'anomalies'. The unit from the Davis Lake pluton has a very "flat" pattern with very low LREE/HREE ratios and large Eu 'anomaly'. The MBMG unit from the West Dalhousie pluton has a very fractionated HREE pattern and a large Eu 'anomaly'.

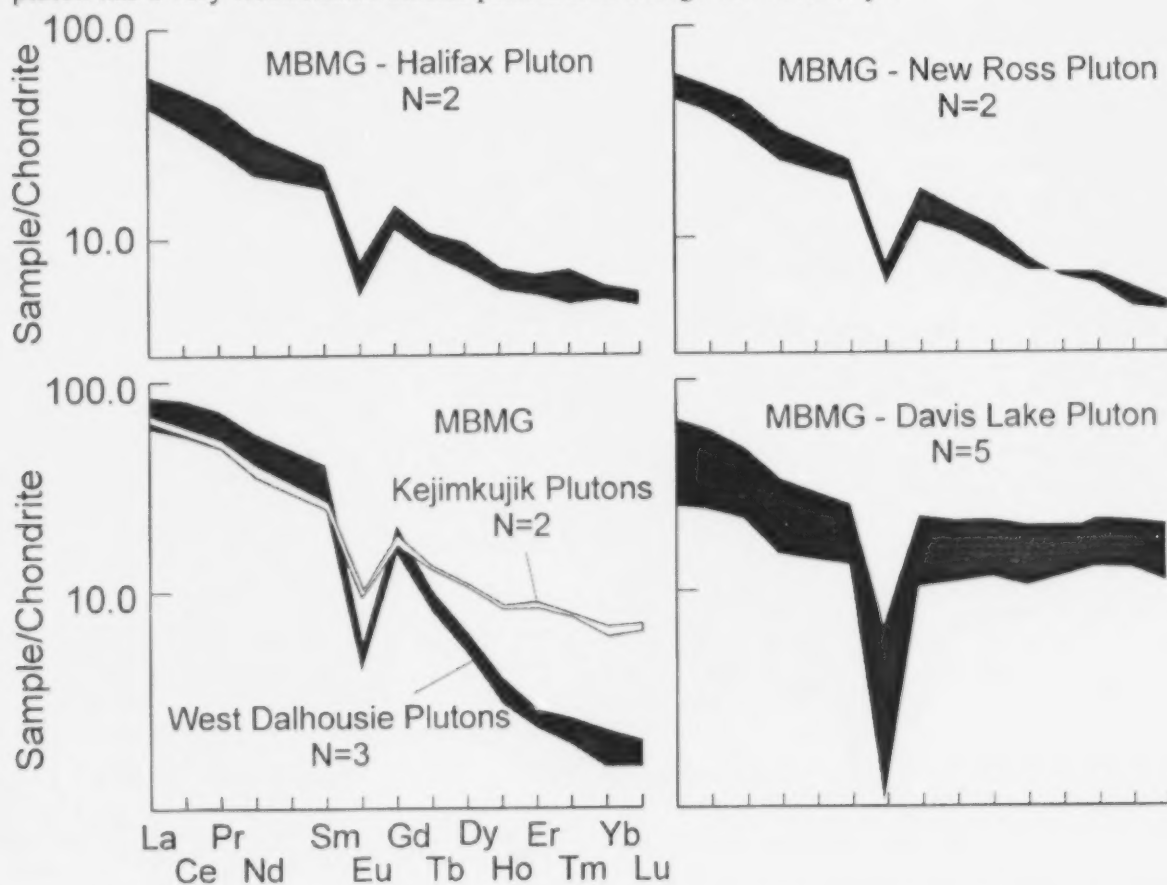


**Figure 5.13** Rare Earth Element (REE) plots for muscovite-biotite monzogranite from the Halifax, New Ross, Kejimikujik, West Dalhousie and Davis Lake Stage II plutons. See text for discussion.

The high values for K/Rb in these rocks preclude an explanation of the observed REE spectra by fluid-related alteration and/or metasomatism. Therefore, the differences in major, trace

and REE data among the various Stage II plutons must result from one or more of the following factors: 1) differing physico-chemical conditions during crystallization of sundry plutons, possibly resulting in differing accessory mineral assemblages (monazite, zircon, xenotime, apatite); 2) differing compositions of the "parental" magmas for the various plutons, presumably reflecting differences in the protolith composition and/or varying degrees of partial melting in the protolith. It is not possible to reconcile the viability of these two processes, given the available data.

### 5.2.3 Geochemistry of Leucogranite Rocks

Leucogranite rocks are the most 'evolved' rocks in the batholith, are frequently spatially associated with, and commonly interpreted to be the progenitors of, polymetallic mineral deposits. Consequently, the chemical make-up of these rocks deserves special attention.

Chemical analyses of muscovite leucogranite rocks (MLG) from the batholith are presented in Appendix A. Previous workers have noted significant differences in the compositions of leucogranitic rocks of the batholith. Kontak et al. (1988) defined two types of leucogranites, corresponding to leucogranite and leucomonzogranite of this study, which were characterized using trace element and  $^{18}\text{O}$  geochemistry. Clarke et al. (1993) also described two leucogranite types using major, trace and rare earth element and  $^{18}\text{O}$  geochemistry. Their "independent" leucogranite bodies correspond to leucogranite of this study whereas their "associated" leucogranites occur as portions of fine-grained leucomonzogranite which have undergone fluid-related alteration. Chatterjee and MacDonald (1993) established a four-fold subdivision of leucogranite using the trace element data in Appendix A and REE geochemistry (unpubl. data A.K. Chatterjee). They noted two main groups: Group A "non-specialized" leucogranites with high K/Rb,  $\text{Eu}/\text{Eu}^*$ , Nb/Ta, and high levels of "compatible" elements (e.g. Ba), and low Rb/Sr

and low concentrations of "incompatible" elements (e.g. F, Li, Rb, Ta, Nb and Sn); and Group B "specialized" leucogranites with high Rb/Sr and high concentrations of "incompatible" elements and low K/Rb,  $\text{Eu}/\text{Eu}^*$ , Nb/Ta, and low levels of "compatible" elements.

Group A non-specialized leucogranites can further be subdivided into  $A_1$ , including the Walsh Brook leucogranites (Corey, 1987). These MLG have high  $\text{P}_2\text{O}_5$  (0.30%) and low MnO (0.03%) compared with average biotite granodiorite compositions (0.21%  $\text{P}_2\text{O}_5$ ; 0.08% MnO). These rocks also have "fractionated" REE patterns (Figure 5.14a) with large  $\text{Gd}/\text{Lu}_N$  (3.64) and  $\text{La}/\text{Lu}_N$  (5.78). A second subgroup  $A_2$ , which includes the Big Indian Lake leucogranites (Corey, 1987), have low  $\text{P}_2\text{O}_5$  (0.15%) and high MnO (0.12%) compared to granodiorite, and have "V" shaped REE spectra (Fig. 5.14b) with very low values of  $\text{Gd}/\text{Lu}_N$  (0.36) and  $\text{La}/\text{Lu}_N$  (0.96).

Group B specialized leucogranites can further be subdivided into  $B^1$  which include the East Kemptville leucogranites and outcrop at, and adjacent to, the East Kemptville Sn mine (Ham and MacDonald, 1994), the Murphy Lake leucogranite (MacDonald and Ham, 1992), and the Keddy-Reeves and Lake Lewis leucogranites from the New Ross area (Horne, 1993; Ham, 1990). Rocks of this subgroup have high  $\text{P}_2\text{O}_5$  (0.44%) and low MnO (0.04%), compared to granodiorite, and display "fractionated" REE patterns (Figure 5.14c) with moderate  $\text{Gd}/\text{Lu}_N$  (3.01) and  $\text{La}/\text{Lu}_N$  (5.40). A second subgroup  $B_2$ , which includes the Davis Lake and Dog Lake leucogranites (Ham and MacDonald, 1994), have low  $\text{P}_2\text{O}_5$  (0.16%) and high MnO (0.08%)



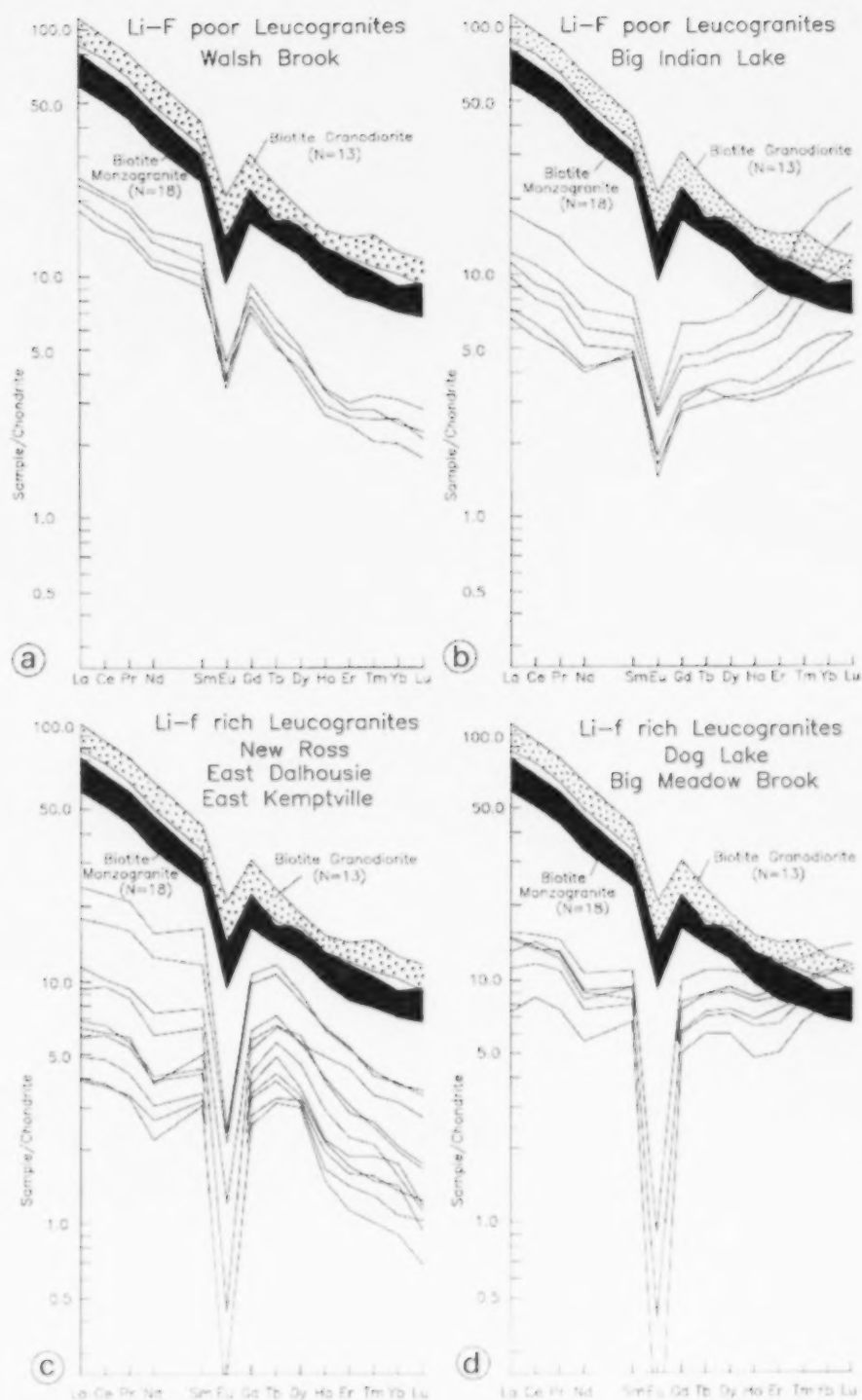


Figure 5.14 Rare earth element (REE) plots for muscovite leucogranites (MLG) from the South Mountain Batholith. See text for discussion.

compared to granodiorite, and have "Wing" shaped REE spectra (Fig. 5.14d) with very low values of  $Gd/Lu_N$  (0.71) and  $La/Lu_N$  (1.30).

Previous studies of leucogranitic rocks in the batholith have concluded, largely based on geochemical parameters, that these rocks have undergone extensive fluid/melt and/or fluid/rock interaction (Kontak et al., 1988; MacDonald and Clarke, 1991; Clarke et al., 1993; Chatterjee and MacDonald, 1993). It is therefore reasonable to conclude that the diverse trace and RE element compositions of leucogranites may be a result of varying degrees of fluid-rock interaction. However, some leucogranite REE spectra mirror the patterns of the host pluton, as shown by the REE spectra for muscovite-biotite monzogranites in the previous section. Perhaps the best example of this is the "flat" REE spectra in samples from the Davis Lake leucogranite that closely resembles the spectra of the nearby Solomon Lake muscovite-biotite monzogranite and strongly contrasts the spectra for both the leucogranite units and the Sherwood Muscovite-biotite monzogranite from the New Ross pluton. Therefore the observed RE, major and trace element and trace element geochemistry of leucogranites are likely as a result of a combination of crystal/melt processes in the rocks of the host pluton and late-stage fluid alteration and/or metasomatism. Whatever the exact explanation for the trace and RE element compositions in leucogranite units the most important observation is that most leucogranite units displays unique, and consistent, chemical characteristics. The wide range of F, Li, Rb, Ta and other "incompatible" elements reveals wide ranges in the degree of "specialization" as defined by Tischendorf (1977). In fact,

some leucogranites are "non-specialized". Therefore, the various leucogranites presumably have varying potential for the generation of mineral deposits. It should be noted that the East Kemptville leucogranite (Kontak, 1990), which is host to the East Kemptville Sn-Cu-Zn-Ag deposit, has some of the highest concentrations of "incompatible" elements (e.g. F and Rb) in the entire batholith. The economic implications of leucogranite composition are further discussed in Chapter 9.

#### 5.2.4 Geochemistry of Aplite Dykes

As previously noted, aplite and pegmatite dykes were observed to intrude all rock types of both Stage I and II plutons but generally constitute only a minor proportion of most map units (e.g.  $< 1\%$ ). In general, dyke rock are more leucocratic than their host rocks, some being leucogranites *sensu stricto* (i.e.  $< 2\%$  combined mafic minerals). Based on these factors dyke rocks have traditionally been considered to have highly "evolved" composition although few comprehensive geochemical studies have been conducted. A detailed study of a series of aplite and aplitic portions of pegmatite-bearing dykes, from an outcrop in the Halifax Pluton, was

undertaken as part of this study, as previously indicated in Chapter 4. Eight aplite samples were submitted for major, trace and RE element analysis.

The eight aplite samples have wide variations for most major element concentrations, including 71.23-76.00%  $\text{SiO}_2$ , 0.93-2.12%  $\text{Fe}_2\text{O}_3$ , 0.10-0.60%  $\text{CaO}$ , 0.42-1.07%  $\text{MgO}$ , 0.05-0.29%  $\text{TiO}_2$  (Table 5.4). These compositional ranges are similar to the entire range for Stage II plutons as listed in Table 5.2. Concentrations of  $\text{Na}_2\text{O}$  (2.42-3.41%) are significantly lower than the average compositions for the major rock types in the batholith whereas  $\text{K}_2\text{O}$  values ( $\leq 6.00\%$ ) far exceed the average concentrations in most of the batholith as shown in Figure 5.15. Concentrations of several "compatible" trace elements, including Ba (58-646 ppm), Sr (14-117 ppm), Zr (27-141 ppm), La (2-36 ppm) and Sc (0.6-4.9 ppm), approximate the entire compositional range for the batholith as shown in Figures 5.15). Concentrations of "incompatible" elements are very low with some elements having lower concentrations than biotite granodiorite, the least evolved rock type, as shown in Figure 5.15.

Rare Earth Element (REE) analyses for the eight aplites from a single outcrop are given in Table 5.5. Chondrite-normalized plots were calculated for the REE using the chondrite abundances of Ensen et al. (1978) and are displayed in Figures 5.16.a,b. A sample of the biotite monzogranite host rock has been included for comparison. Several observations can be made regarding the REE data. First, there are very large variations in the overall concentrations of the REE and the shape of the spectra from those that approximate the host monzogranite (e.g. 103-A1) to highly depleted spectra (e.g. 103-A2, -A3, -A8, Group II aplites in Figure 5.15).

All samples in Figure 5.16a have lower  $\Sigma\text{REE}$  but similar La/Sm and Gd/Lu as the host monzogranite. These samples, along with 103-A1, constitute Group I aplites in Figure 5.15. Conversely, the samples plotted in Figure 5.16b have very "flat" to "wing shaped" REE spectra

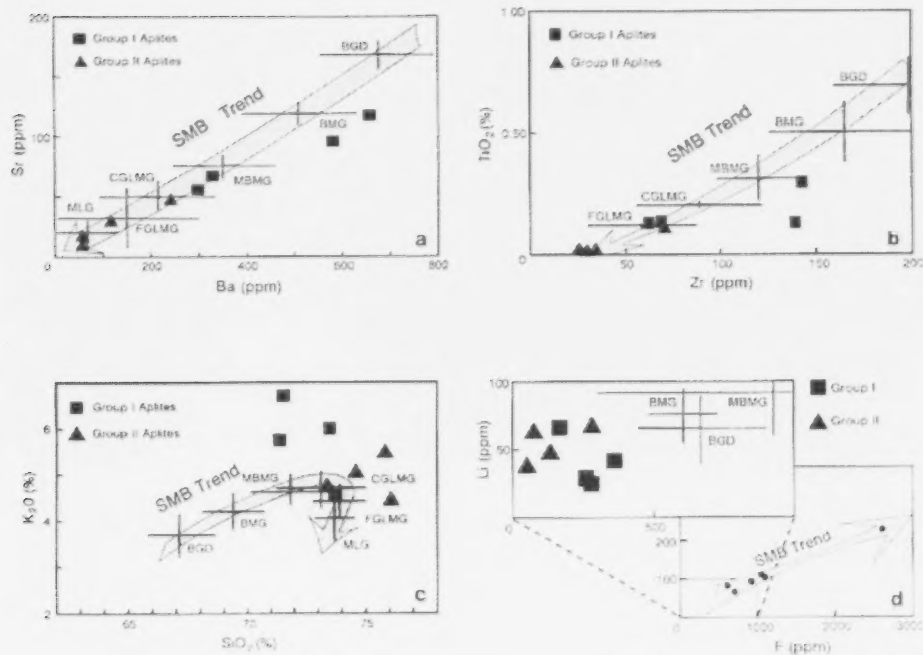
**Table 5.4.** Major and trace element contents of aplites from outcrop of Sandy Lake Biotite Monzogranite, Halifax Pluton.

| Sample #                          | 103-A1 | 103-A2 | 103-A3 | 103-A4 | 103-A5 | 103-A6 | 103-A8 | 103-A9 |
|-----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| <b>Major Oxides</b>               |        |        |        |        |        |        |        |        |
| SiO <sub>2</sub>                  | 71.27  | 73.50  | 71.23  | 73.75  | 75.79  | 76.00  | 73.26  | 74.73  |
| Al <sub>2</sub> O <sub>3</sub>    | 14.57  | 14.14  | 15.15  | 14.49  | 13.45  | 13.97  | 14.42  | 14.19  |
| Fe <sub>2</sub> O <sub>3(T)</sub> | 2.12   | 1.39   | 1.18   | 1.56   | 0.93   | 0.95   | 1.45   | 0.78   |
| CaO                               | 0.60   | 0.32   | 0.32   | 0.29   | 0.10   | 0.10   | 0.28   | 0.17   |
| MgO                               | 1.07   | 0.68   | 0.68   | 0.62   | 0.48   | 0.42   | 0.64   | 0.58   |
| Na <sub>2</sub> O                 | 2.77   | 2.42   | 2.46   | 3.10   | 2.71   | 3.41   | 3.04   | 2.71   |
| K <sub>2</sub> O                  | 5.75   | 6.00   | 6.77   | 4.53   | 5.50   | 4.59   | 4.74   | 4.93   |
| TiO <sub>2</sub>                  | 0.29   | 0.15   | 0.13   | 0.13   | 0.05   | 0.03   | 0.14   | 0.02   |
| MnO                               | 0.04   | 0.05   | 0.05   | 0.07   | 0.04   | 0.06   | 0.07   | 0.05   |
| P <sub>2</sub> O <sub>5</sub>     | 0.32   | 0.25   | 0.34   | 0.19   | 0.15   | 0.25   | 0.28   | 0.17   |
| LOI                               | 0.30   | 0.40   | 0.70   | 0.40   | 0.10   | 0.40   | 0.50   | 0.60   |
| Total                             | 99.11  | 99.30  | 99.03  | 99.15  | 99.31  | 100.18 | 98.82  | 98.93  |
| <b>Trace Elements</b>             |        |        |        |        |        |        |        |        |
| Ba                                | 646    | 327    | 574    | 294    | 62     | 58     | 248    | 115    |
| Rb                                | 179    | 169    | 188    | 214    | 170    | 237    | 218    | 153    |
| Sr                                | 117    | 65     | 95     | 51     | 19     | 14     | 50     | 32     |
| Zr                                | 141    | 57     | 66     | 138    | 34     | 25     | 70     | 27     |
| Nb                                | 8      | 5      | <5     | <5     | <5     | <5     | 7      | <5     |
| V                                 | 12     | 8      | <5     | 7      | <5     | <5     | <5     | <5     |
| Y                                 | 16     | 9      | 9      | 31     | 9      | <5     | 8      | 5      |
| Ga                                | 17     | 15     | 16     | 16     | 17     | 21     | 17     | 17     |
| Zn                                | 41     | 21     | 21     | 28     | 15     | 15     | 28     | 11     |
| Sc                                | 4.9    | 3.6    | 2.8    | 4.4    | 1.5    | 1.1    | 3.4    | 0.6    |
| Hf                                | 4      | 2      | 3      | 4      | 1      | <1     | 1      | <1     |
| Th                                | 12.0   | 5.4    | 4.3    | 9.3    | 3.1    | 1.3    | 6.3    | 1.7    |
| U                                 | 4.3    | 5.5    | 5.3    | 13.0   | 6.7    | 6.8    | 3.5    | 3.8    |
| Ta                                | <0.5   | 1.4    | 1.1    | 1.4    | 0.5    | 1.1    | 2.1    | <0.5   |
| Cs                                | 6.2    | 3.7    | 4.6    | 8.1    | 4.1    | 19.0   | 17.0   | 5.8    |
| W                                 | <1     | <1     | <1     | <1     | <1     | 1      | 1      | <1     |
| Sn                                | 4      | 13     | 20     | 21     | 14     | 22     | 21     | 19     |
| Li                                | 39     | 26     | 25     | 64     | 68     | 49     | 68     | 37     |
| F                                 | 350    | 252    | 269    | 160    | 63     | 124    | 273    | 50     |
| B                                 | 15     | 15     | 26     | 32     | 14     | 20     | 40     | 27     |
| La                                | 36     | 12     | 12     | 18     | 3      | 2      | 14     | 3      |
| K/Rb                              | 266    | 294    | 298    | 175    | 268    | 160    | 180    | 267    |

Table 5.5. Rare Earth Element (REE) analytical results for aplites and host biotite monzogranite, Halifax Pluton.

| Sample #<br>Rock Type | 103-A1<br>APLI | 103-A2<br>APLI | 103-A3<br>APLI | 103-A4<br>APLI | 103-A5<br>APLI | 103-A6<br>APLI | 103-A8<br>APLI | 103-A9<br>APLI | ASPO-2<br>BMG |
|-----------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|---------------|
| Element               |                |                |                |                |                |                |                |                |               |
| La                    | 26.40          | 10.25          | 9.99           | 14.87          | 2.49           | 1.74           | 11.43          | 1.86           | 22.66         |
| Ce                    | 60.72          | 23.49          | 23.33          | 32.92          | 5.72           | 3.69           | 25.51          | 4.16           | 50.29         |
| Pr                    | 7.44           | 2.90           | 2.86           | 3.92           | 0.73           | 0.50           | 3.18           | 0.52           | 6.16          |
| Nd                    | 26.69          | 11.84          | 10.83          | 14.73          | 2.84           | 1.82           | 12.53          | 1.90           | 23.52         |
| Sm                    | 7.18           | 3.17           | 3.17           | 3.93           | 1.11           | 1.04           | 3.48           | 0.71           | 5.23          |
| Eu                    | 0.82           | 0.44           | 0.64           | 0.34           | 0.10           | 0.07           | 0.35           | 0.19           | 0.74          |
| Gd                    | 5.82           | 2.65           | 3.15           | 4.10           | 1.15           | 0.80           | 2.95           | 0.87           | 4.66          |
| Tb                    | 0.71           | 0.40           | 0.49           | 0.72           | 0.25           | 0.17           | 0.45           | 0.21           | 0.80          |
| Py                    | 3.80           | 2.38           | 2.92           | 5.06           | 1.97           | 1.32           | 2.41           | 1.56           | 4.97          |
| Ho                    | 0.56           | 0.38           | 0.42           | 1.03           | 0.40           | 0.25           | 0.41           | 0.28           | 0.91          |
| Er                    | 1.51           | 1.03           | 1.11           | 3.30           | 1.30           | 0.77           | 1.02           | 0.88           | 2.60          |
| Tm                    | 0.20           | 0.15           | 0.16           | 0.54           | 0.19           | 0.17           | 0.16           | 0.16           | 0.37          |
| Yb                    | 1.27           | 0.99           | 0.97           | 3.73           | 1.48           | 1.33           | 1.17           | 1.26           | 2.24          |
| Lu                    | 0.16           | 0.13           | 0.11           | 0.55           | 0.22           | 0.19           | 0.17           | 0.18           | 0.33          |

Rock Type - APLI - Aplitite; BMG - biotite monzogranite

Figure 5.15 Bivariate plots of Sr vs Ba; TiO<sub>2</sub> vs Zr; K<sub>2</sub>O vs SiO<sub>2</sub>; and Li vs F for 8 aplitite samples from the Halifax Pluton. Overall compositional trends for the SMB have been plotted for comparison. See text for discussion.



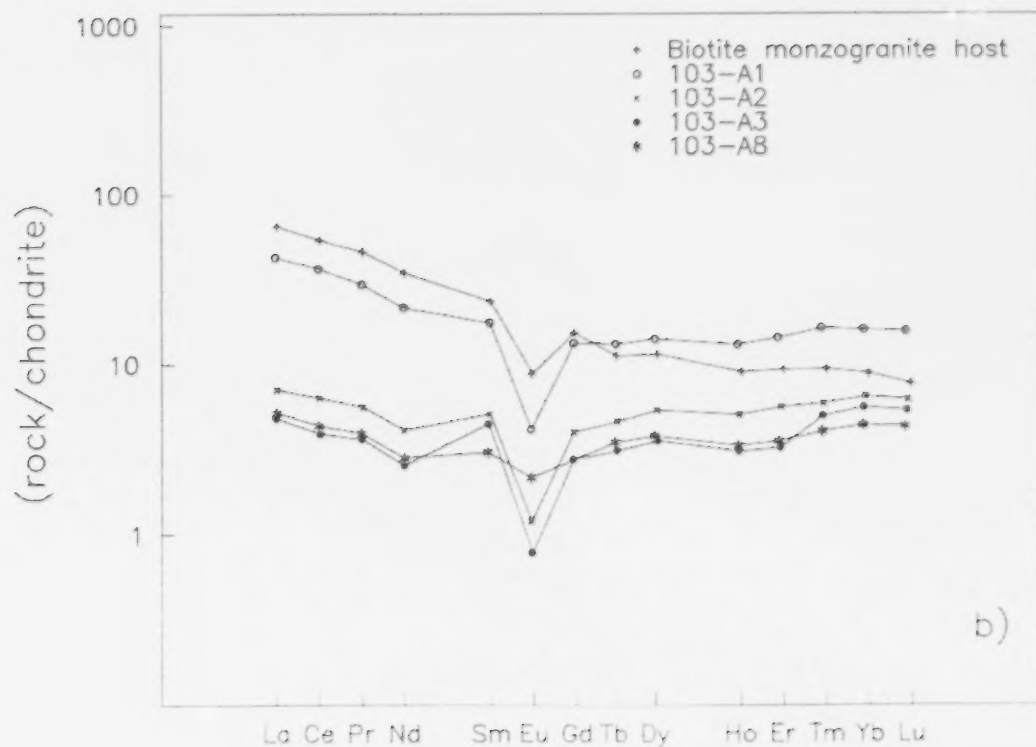
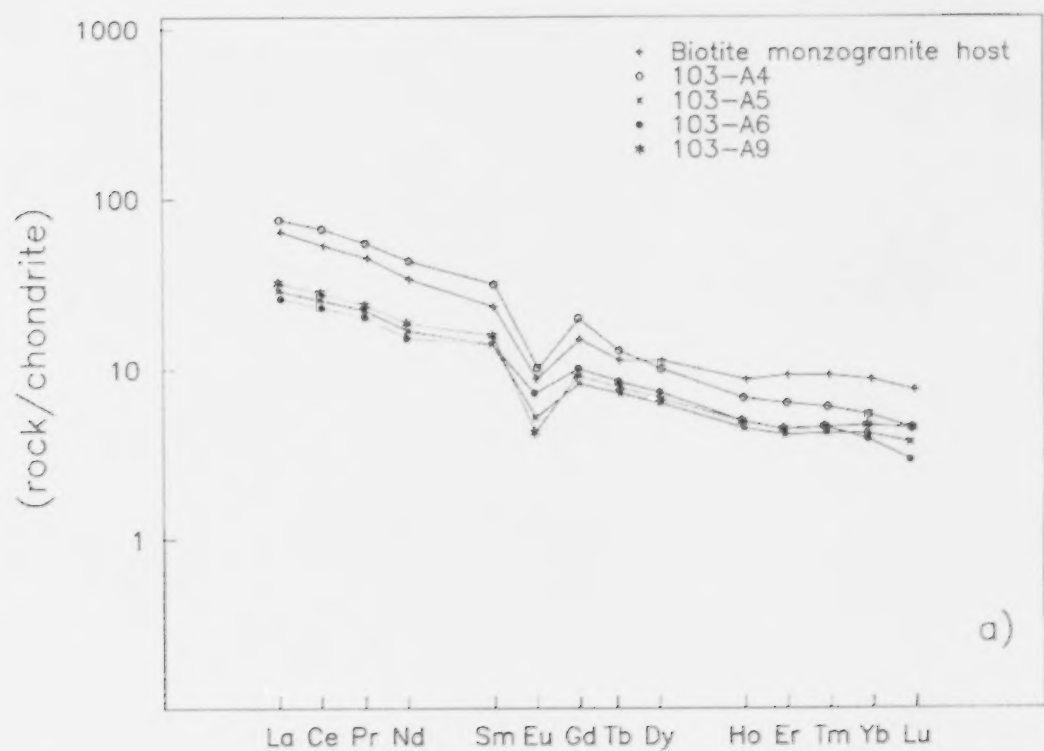


Figure 5.16 Rare earth element (REE) plots for 8 aplite samples from the Halifax Pluton. See text for discussion.

with very low (La/Sm) and Gd/Lu, in fact these aplites have positive slopes for the "heavy" REE (i.e. Gd to Lu) that are unlike the REE spectra of the biotite monzogranite host rock.

Several observations can be made on the basis of the above geochemistry. First, all of the major, trace and REE data demonstrate large compositional variations in aplite and aplite/pegmatite dykes from a single outcrop in the Halifax Pluton. Sample 103-A1 has the highest modal proportion of biotite in the sample set and has very similar chemical composition to its host biotite monzogranite. In contrast, the more "evolved" dykes (i.e. 103-A5, 103-A6) have very low "compatible" trace elements and REE compared to host rocks. All dykes have low concentrations of "incompatible" elements when compared to average concentrations for the major rock types of the batholith. In fact, none of the examined dykes satisfy the chemical criteria for "specialized" granites (as outlined by Tischendorf, 1977), despite several are classified as leucogranites (i.e.  $< 2\%$  combined mafic minerals). The presence of two distinct types of REE spectra conflicts with a model for dyke generation that involves fractional crystallization from the monzogranite host. The low levels of "incompatible" elements may reflect the presence of contemporaneous pegmatites in the outcrop. It is probable that some elements including F and Li were selectively partitioned into the volatile-rich pegmatite melt during second or resurgent boiling (Hyndman, 1972) which would explain the low levels of these elements in the aplites. It is also possible that some of the REE distribution may be attributed to fluid-stripping within the granite melt, as noted by Muecke and Clarke (1981), although this is highly speculative based on the above data. In summary, the suite of aplite dykes from a single outcrop in the Halifax Pluton has a wide range of compositions. It is not clear whether these observations can be applied to aplite dykes throughout the batholith.

### 5.2.5 Geochemistry of Mafic Porphyry Rocks

Mafic porphyry rocks were mapped in both Stage I and II plutons throughout the batholith. Mafic porphyry units typically contain abundant metasedimentary xenoliths and are situated at or near granite/metasedimentary rock contacts, with the exception of those in the Halifax and New Ross Stage II plutons. Mafic porphyry rocks are characterized by a wide range of grain size, texture and modal mineralogy, as previously noted in previous chapters. Most map bodies are small ( $<1 \text{ km}^2$ ) and, consequently, only a small number of samples have previously been chemically analyzed (Ham et al., 1989, 1990). A compendium of analyses for mafic porphyry from the entire batholith is given in Table 5.6. It is clear from these data that mafic porphyries have highly variable major and trace element geochemistry.

A mesonormative plot (after LeMaitre, 1989) for the four mafic porphyry bodies is given in Figure 5.17. Two samples that were collected approximately 300 m apart in the Sambro mafic porphyry body from the Halifax Pluton have dissimilar compositions, although both samples plot in the granodiorite field. Sample D12-3059 (70.13%  $\text{SiO}_2$ ; 2.50%  $\text{Fe}_2\text{O}_3$ ; 220 ppm Rb; 89 ppm Sr) is very similar in composition to muscovite-biotite monzogranite from the Halifax Pluton (71.07%  $\text{SiO}_2$ ; 2.83%  $\text{Fe}_2\text{O}_3$ ; 242 ppm Rb; 92 ppm Sr) whereas sample D12-3061 (67.94%  $\text{SiO}_2$ ; 3.98%  $\text{Fe}_2\text{O}_3$ ; 135 ppm Rb; 151 ppm Sr) resembles the composition of biotite granodiorite from the same pluton (67.79%  $\text{SiO}_2$ ; 4.10%  $\text{Fe}_2\text{O}_3$ ; 164 ppm Rb; 171 ppm Sr). Four samples from the Lequille mafic porphyry (Corey and Horne, 1994b) have uniform compositions (63.27-64.47%  $\text{SiO}_2$ ; 6.16-6.23%  $\text{Fe}_2\text{O}_3$ ; 135-145 ppm Rb; 175-189 ppm Sr) and plot along the granodiorite/monzogranite join on LeMaitre's (1989) plot. Both samples from the mafic porphyry body near Big St. Margaret's Bay (Ham and Horne, 1987) have similar compositions and plot

Table 5.6 Major and trace element analyses and normative mineralogy  
for mafic porphyry bodies from the SMB

| SAMPLE<br>Pluton               | D05-3059<br>HP | D05-3060<br>HP | A16-3046<br>NRP | A16-3047<br>NRP | A11-2270-C<br>SGP | LQ-92-1<br>SGP | LQ-92-2<br>SGP | LQ-92-3<br>SGP | A10-3052<br>STP |
|--------------------------------|----------------|----------------|-----------------|-----------------|-------------------|----------------|----------------|----------------|-----------------|
| Major Elements (wt %)          |                |                |                 |                 |                   |                |                |                |                 |
| SiO <sub>2</sub>               | 70.13          | 67.94          | 69.50           | 70.01           | 63.82             | 64.47          | 63.91          | 63.27          | 67.22           |
| Al <sub>2</sub> O <sub>3</sub> | 14.65          | 14.84          | 14.47           | 14.28           | 16.09             | 16.08          | 16.09          | 16.39          | 15.36           |
| Fe <sub>2</sub> O <sub>3</sub> | 2.50           | 3.98           | 3.68            | 3.46            | 6.36              | 6.23           | 6.11           | 6.16           | 4.37            |
| CaO                            | 1.21           | 2.32           | 0.87            | 0.97            | 1.74              | 1.94           | 1.95           | 2.1            | 1.26            |
| MgO                            | 3.60           | 2.12           | 1.64            | 1.50            | 2.12              | 1.62           | 1.67           | 1.64           | 1.78            |
| Na <sub>2</sub> O              | 3.63           | 4.56           | 3.43            | 3.93            | 3.14              | 2.91           | 2.86           | 2.91           | 3.21            |
| K <sub>2</sub> O               | 4.14           | 3.49           | 4.12            | 4.35            | 3.47              | 3.65           | 3.67           | 3.72           | 4.25            |
| TiO <sub>2</sub>               | 0.29           | 0.56           | 0.51            | 0.47            | 0.85              | 0.84           | 0.84           | 0.82           | 0.87            |
| P <sub>2</sub> O <sub>5</sub>  | 0.20           | 0.20           | 0.21            | 0.21            | 0.23              | 0.23           | 0.23           | 0.23           | 0.21            |
| MnO                            | 0.07           | 0.08           | 0.06            | 0.07            | 0.17              | 0.13           | 0.12           | 0.13           | 0.07            |
| H <sub>2</sub> O               | 0.50           | 0.70           | 0.80            | 0.70            | 1.20              | 0.9            | 1.1            | 0.9            | 0.67            |
| Normative Mineralogy           |                |                |                 |                 |                   |                |                |                |                 |
| Q                              | 25.65          | 20.57          | 30.51           | 26.97           | 26.56             | n.d.           | n.d.           | n.d.           | 27.90           |
| OR                             | 24.39          | 20.62          | 24.74           | 25.92           | 20.95             | n.d.           | n.d.           | n.d.           | 25.50           |
| AB                             | 30.58          | 38.55          | 29.47           | 33.50           | 27.11             | n.d.           | n.d.           | n.d.           | 27.54           |
| AN                             | 4.67           | 9.70           | 2.99            | 3.46            | 7.27              | n.d.           | n.d.           | n.d.           | 4.95            |
| C                              | 2.46           | 0.00           | 3.34            | 1.86            | 4.65              | n.d.           | n.d.           | n.d.           | 3.74            |
| EN                             | 8.93           | 5.10           | 4.15            | 3.76            | 5.39              | n.d.           | n.d.           | n.d.           | 4.50            |
| IL                             | 0.15           | 0.17           | 0.13            | 0.15            | 0.37              | n.d.           | n.d.           | n.d.           | 0.15            |
| HM                             | 2.49           | 3.98           | 3.74            | 3.49            | 6.49              | n.d.           | n.d.           | n.d.           | 4.43            |
| RU                             | 0.21           | 0.47           | 0.45            | 0.39            | 0.67              | n.d.           | n.d.           | n.d.           | 0.80            |
| AP                             | 0.46           | 0.46           | 0.49            | 0.49            | 0.54              | n.d.           | n.d.           | n.d.           | 0.49            |
| A/CNK                          | 1.16           | 0.96           | 1.24            | 1.10            | 1.33              | n.d.           | n.d.           | n.d.           | 1.26            |
| TTDI                           | 80.62          | 79.74          | 84.72           | 86.39           | 74.61             | n.d.           | n.d.           | n.d.           | 80.94           |
| Col. Ind.                      | 11.57          | 9.63           | 8.01            | 7.40            | 12.25             | n.d.           | n.d.           | n.d.           | 9.08            |
| Trace Elements (ppm)           |                |                |                 |                 |                   |                |                |                |                 |
| Ba                             | 262            | 446            | 483             | 467             | 744               | 756            | 755            | 694            | 888             |
| Rb                             | 220            | 182            | 210             | 217             | 135               | 145            | 141            | 144            | 153             |
| Sr                             | 89             | 151            | 118             | 99              | 181               | 189            | 175            | 175            | 132             |
| Zr                             | 90             | 148            | 160             | 152             | 294               | 282            | 282            | 287            | 222             |
| Nb                             | 10             | 12             | 12              | 12              | 14                | 15             | 15             | 14             | 9               |
| V                              | 20             | 50             | 40              | 36              | 97                | 84             | 76             | 83             | 69              |
| Y                              | 22             | 22             | 25              | 25              | 46                | 46             | 43             | 48             | 32              |
| Ga                             | 19             | 20             | 26              | 22              | 17                | 21             | 22             | 23             | 19              |
| Cu                             | 0              | 4              | 5               | 0               | 7                 | 19             | 20             | 17             | 8               |
| Zn                             | 43             | 74             | 73              | 57              | 790               | 94             | 79             | 81             | 70              |
| Hf                             | 3              | 3              | 4               | 4               | 8                 | 7              | 7              | 7              | 6               |
| Ta                             | 1.1            | 1.6            | 1.5             | 1.5             | 1.4               | 1.5            | 0.9            | 1.2            | 1.1             |
| Sc                             | 8.8            | 5.5            | 8.5             | 7.9             | 14.0              | 16             | 16             | 17             | 9.4             |
| La                             | 27             | 16             | 31              | 29              | 45                | 51             | 50             | 48             | 38              |
| Th                             | 12.0           | 8.0            | 11.0            | 11.0            | 15.0              | 15             | 15             | 14             | 16.0            |
| U                              | 3.6            | 4.4            | 4.3             | 2.9             | 3.6               | 3.4            | 3.6            | 3.4            | 4.1             |
| Li                             | 95             | 94             | 73              | 73              | 66                | 62             | 59             | 51             | 31              |
| F                              | 710            | 590            | 640             | 690             | 674               | 641            | 611            | 661            | 660             |
| As                             | 6.1            | 2.4            | 4.3             | 1.2             | 9.0               | 8.4            | 8.3            | 7.4            | 8.2             |
| Sn                             | 15             | 12             | 11              | 10              | 0                 | 7              | 2              | 2              | 2               |
| W                              | 1              | 1              | 1               | 1               | 0                 | 0.5            | 0.5            | 0.5            | 0               |

n.d. - not determined

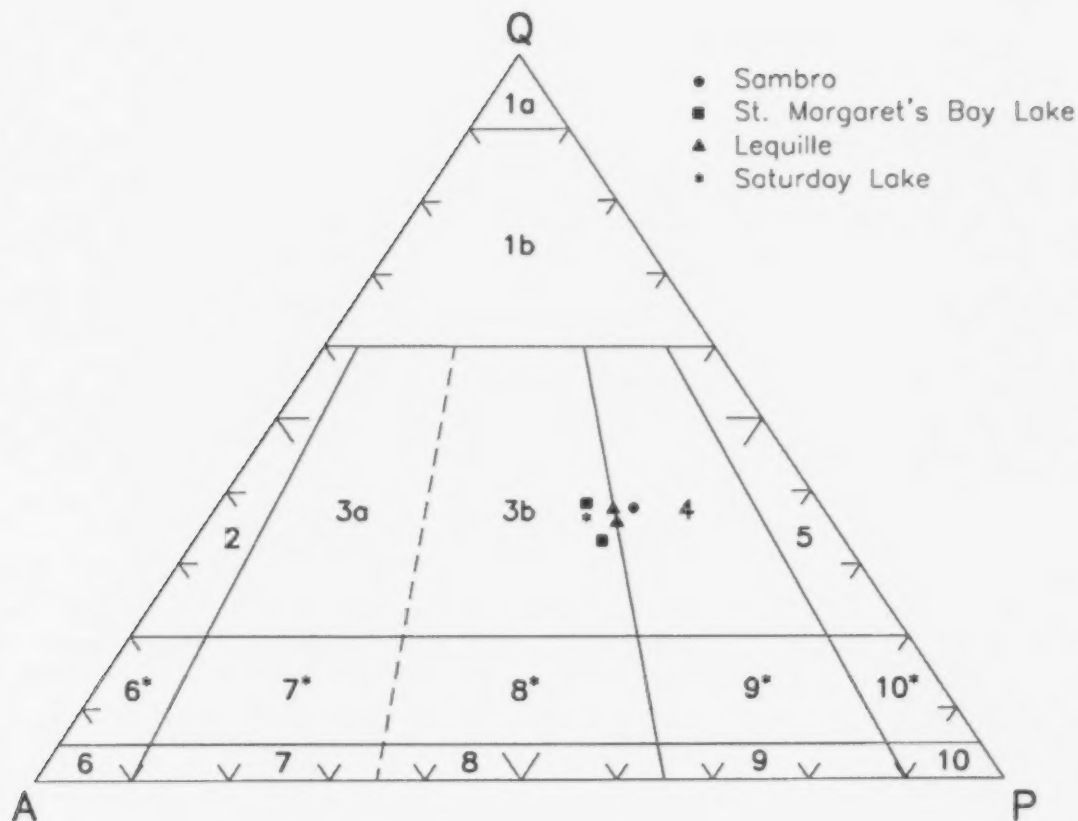


Figure 5.17 Ternary plot of average CIPW normative data for mafic porphyry rocks from the entire SMB (fields after LeMaitre, 1989). See text for discussion.

in the monzogranite field of Lemaitre (1989).

In light of the above results a geochemical study of the Boot Lake granodiorite/mafic porphyry body (MacDonald and Ham, 1992) was undertaken. A suite of 19 samples was collected and analyzed for major and trace elements by the methods outlined in Section 5.1. Analytical results are given in Table 5.7. Rocks designated "hybrid" are mafic porphyry with abundant garnet  $\pm$  pyrite  $\pm$  arsenopyrite that form "swirling" or wispy bands in Halifax Formation slate with ptygmatic folds. Rocks designated "garnet-bearing mafic porphyry" have common to abundant orange-red garnet with common pyrite and arsenopyrite and are situated adjacent to large blocks

Table 5.7 Major and trace element analyses for the Boot Lake unit (after MacDonald and Ham, 1992)

| Rock Type                      | HR       | HR       | HR       | GMP      | GMP      | BRGD     | BRGD     | BRGD     | BRGD      | BRGD      | BRGD      |
|--------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|-----------|
| Sample                         | A15-80-8 | A15-80-9 | A15-0087 | A15-80-5 | A15-80-6 | A15-0080 | A15-0081 | A15-80-7 | A15-80-10 | A15-80-11 | A15-80-13 |
| Major Elements (wt. %)         |          |          |          |          |          |          |          |          |           |           |           |
| SiO <sub>2</sub>               | 69.48    | 65.34    | 60.85    | 65.96    | 62.92    | 64.72    | 65.36    | 64.45    | 62.67     | 62.24     | 65.01     |
| Al <sub>2</sub> O <sub>3</sub> | 16.01    | 17.51    | 18.70    | 16.72    | 17.08    | 16.63    | 15.33    | 15.95    | 16.47     | 16.19     | 16.58     |
| Fe <sub>2</sub> O <sub>3</sub> | 4.96     | 5.88     | 6.36     | 5.89     | 6.64     | 4.89     | 5.98     | 6.16     | 7.50      | 7.64      | 5.09      |
| MgO                            | 1.04     | 1.59     | 0.96     | 1.81     | 1.93     | 3.07     | 2.38     | 1.58     | 1.74      | 1.80      | 1.56      |
| CaO                            | 1.68     | 1.12     | 2.04     | 2.30     | 2.50     | 2.13     | 1.80     | 2.22     | 3.04      | 3.09      | 3.21      |
| Na <sub>2</sub> O              | 2.75     | 2.38     | 2.13     | 2.79     | 2.71     | 3.98     | 3.33     | 3.18     | 3.16      | 3.21      | 3.71      |
| K <sub>2</sub> O               | 1.50     | 3.19     | 4.48     | 2.37     | 3.23     | 2.64     | 3.46     | 3.06     | 3.20      | 2.87      | 2.73      |
| TiO <sub>2</sub>               | 0.68     | 0.80     | 0.88     | 0.88     | 0.99     | 0.77     | 0.82     | 0.85     | 1.06      | 1.05      | 0.79      |
| MnO                            | 0.08     | 0.14     | 0.16     | 0.42     | 0.44     | 0.28     | 0.24     | 0.11     | 0.14      | 0.13      | 0.07      |
| P <sub>2</sub> O <sub>5</sub>  | 0.24     | 0.18     | 0.18     | 0.11     | 0.22     | 0.08     | 0.11     | 0.32     | 0.32      | 0.31      | 0.32      |
| LOI                            | 1.80     | 2.00     | 2.48     | 0.50     | 1.10     | 0.40     | 0.41     | 0.80     | 0.30      | 0.60      | 0.20      |
| Trace Elements (ppm)           |          |          |          |          |          |          |          |          |           |           |           |
| Ba                             | 311      | 626      | 1101     | 533      | 817      | 562      | 819      | 657      | 1040      | 939       | 531       |
| Rb                             | 81       | 126      | 164      | 116      | 161      | 141      | 130      | 138      | 131       | 129       | 148       |
| Sr                             | 195      | 135      | 166      | 187      | 208      | 209      | 179      | 180      | 206       | 208       | 202       |
| Zr                             | 257      | 218      | 220      | 246      | 260      | 162      | 286      | 280      | 333       | 338       | 163       |
| Nb                             | 14       | 15       | 15       | 13       | 17       | 12       | 15       | 17       | 20        | 19        | 11        |
| V                              | 48       | 91       | 106      | 78       | 95       | 61       | 65       | 68       | 82        | 85        | 58        |
| Y                              | 47       | 39       | 43       | 43       | 49       | 27       | 48       | 60       | 55        | 49        | 24        |
| Ga                             | 20       | 21       | 25       | 20       | 23       | 22       | 21       | 20       | 20        | 21        | 19        |
| Cu                             | 15       | 28       | 35       | 12       | 19       | 28       | 13       | 10       | 19        | 14        | 28        |
| Zn                             | 72       | 102      | 98       | 75       | 102      | 83       | 84       | 63       | 88        | 89        | 79        |
| Hf                             | 8        | 7        | 7        | 7        | 7        | 5        | 10       | 8        | 10        | 10        | 4         |
| Ta                             | 1.4      | 1.5      | 1.3      | 1.2      | 1.3      | 1.0      | 1.4      | 1.3      | 1.5       | 1.5       | 1.2       |
| Sc                             | 23.7     | 22.7     | 15.0     | 20.6     | 24.2     | 13.0     | 16.0     | 24.0     | 24.6      | 23.7      | 16.0      |
| La                             | 53       | 51       | 51       | 54       | 59       | 25       | 48       | 53       | 63        | 65        | 24        |
| Th                             | 18.0     | 16.0     | 15.0     | 16.0     | 17.0     | 8.4      | 15.0     | 15.0     | 18.0      | 19.0      | 7.2       |
| U                              | 3.2      | 5.1      | 4.2      | 3.4      | 3.8      | 4.2      | 3.4      | 3.4      | 1.8       | 1.7       | 4.1       |
| Li                             | 45       | 46       | 69       | 40       | 23       | 65       | 51       | 52       | 47        | 58        | 50        |
| F                              | 372      | 366      | 450      | 557      | 873      | 635      | 710      | 740      | 600       | 601       | 477       |
| As                             | 3.5      | 11.0     | 18.0     | 28.0     | 24.0     | 1.7      | 3.8      | 11.0     | 2.0       | 2.6       | 1.1       |
| Sn                             | 2        | 2        | 0        | 2        | 2        | 0        | 2        | 8        | 7         | 7         | 2         |
| W                              | 0.5      | 1        | 0        | 1        | 0.5      | 0        | 0        | 0.5      | 0.5       | 1         | 0.5       |

Rock Types: HR - hybrid rocks; GMP - garnet-rich mafic porphyry; BRGD - biotite-rich granodiorite; G-FGLMG - garnet-bearing fine-grained leucomonzogranite; BMG - biotite monzogranite; MBMG - muscovite-biotite monzogranite; FGLMG - fine-grained leucomonzogranite.

### Symbols

|                                      |         |     |
|--------------------------------------|---------|-----|
| Hybrid Rocks                         | HR      | - + |
| Garnet-rich mafic porphyry           | GMP     | - * |
| Biotite-rich granodiorite            | BRGD    | - X |
| Garnet-bearing f-g leucomonzogranite | G-FGLMG | - ◆ |
| Biotite monzogranite                 | BMG     | - ● |
| Muscovite-biotite monzogranite       | MBMG    | - ○ |
| Fine-grained leucomonzogranite       | FGLMG   | - ■ |



| Rock Type | BRGD      | MBMG      | MBMG      | MBMG      | MBMG      | G-FGLMG   | G-FGLMG   | G-FGLMG   | BMG     | BMG       | BMG       |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|---------|-----------|-----------|
| Sample    | A15-80-18 | 15-0080-2 | A15-80-12 | A15-80-14 | A15-80-15 | A15-80-16 | A15-80-17 | 15-0087-G | A15-116 | A15-116-2 | A15-116-3 |

## Major Elements (wt. %)

|                                |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | 64.98 | 70.58 | 70.34 | 75.05 | 71.00 | 71.84 | 68.91 | 68.73 | 68.30 | 68.77 | 69.05 |
| Al <sub>2</sub> O <sub>3</sub> | 15.82 | 15.30 | 15.33 | 13.90 | 15.09 | 15.69 | 16.77 | 17.01 | 14.80 | 14.73 | 14.39 |
| Fe <sub>2</sub> O <sub>3</sub> | 6.16  | 2.25  | 2.12  | 0.81  | 2.13  | 1.03  | 0.73  | 0.76  | 4.29  | 4.05  | 4.28  |
| MgO                            | 1.57  | 1.33  | 0.75  | 0.16  | 0.67  | 0.01  | 0.00  | 0.89  | 1.73  | 1.63  | 1.59  |
| CaO                            | 2.20  | 1.37  | 1.18  | 1.57  | 1.39  | 0.74  | 0.35  | 0.72  | 1.45  | 1.43  | 1.40  |
| Na <sub>2</sub> O              | 3.05  | 3.99  | 3.06  | 2.73  | 3.28  | 3.47  | 2.78  | 4.42  | 3.24  | 3.45  | 3.36  |
| K <sub>2</sub> O               | 3.06  | 3.95  | 4.39  | 3.90  | 3.93  | 5.56  | 8.54  | 6.02  | 3.97  | 4.24  | 4.23  |
| TiO <sub>2</sub>               | 0.87  | 0.31  | 0.31  | 0.11  | 0.28  | 0.02  | 0.03  | 0.03  | 0.56  | 0.53  | 0.56  |
| MnO                            | 0.11  | 0.17  | 0.05  | 0.02  | 0.06  | 0.18  | 0.15  | 0.21  | 0.20  | 0.19  | 0.18  |
| P <sub>2</sub> O <sub>5</sub>  | 0.31  | 0.06  | 0.23  | 0.07  | 0.20  | 0.22  | 0.26  | 0.14  | 0.09  | 0.09  | 0.09  |
| LOI                            | 1.40  | 0.50  | 0.60  | 0.20  | 0.60  | 0.60  | 0.40  | 0.34  | 0.40  | 0.11  | 0.12  |

## Trace Elements (ppm)

|    |      |      |      |      |     |     |     |      |      |      |      |
|----|------|------|------|------|-----|-----|-----|------|------|------|------|
| Ba | 687  | 551  | 423  | 1500 | 323 | 294 | 485 | 394  | 581  | 599  | 625  |
| Rb | 139  | 141  | 162  | 96   | 190 | 194 | 331 | 240  | 151  | 172  | 164  |
| Sr | 179  | 150  | 135  | 201  | 106 | 57  | 75  | 97   | 133  | 124  | 119  |
| Zr | 270  | 97   | 95   | 84   | 73  | 30  | 23  | 43   | 214  | 200  | 211  |
| Nb | 17   | 8    | 9    | <5   | 9   | <5  | <5  | 0    | 13   | 12   | 12   |
| V  | 67   | 27   | 27   | <5   | 24  | <5  | <5  | 0    | 36   | 41   | 40   |
| Y  | 61   | 16   | 12   | <5   | 13  | 7   | <5  | 22   | 45   | 43   | 46   |
| Ga | 21   | 17   | 17   | 11   | 17  | 15  | 16  | 16   | 18   | 19   | 20   |
| Cu | 11   | 0    | <5   | 5    | <5  | 13  | 23  | 89   | 8    | 9    | 10   |
| Zn | 64   | 45   | 33   | 14   | 46  | 11  | 10  | 11   | 60   | 59   | 68   |
| Hf | 10   | 3    | 3    | 3    | 2   | 2   | 1   | 2    | 7    | 7    | 6    |
| Ta | 1.1  | 0.6  | 1.1  | 0.2  | 1.4 | 0.2 | 0.2 | 0.0  | 1.2  | 1.3  | 1.0  |
| Sc | 26.6 | 5.7  | 6.8  | 2.3  | 6.9 | 4.9 | 4.0 | 2.9  | 11.0 | 10.0 | 10.0 |
| La | 55   | 21   | 22   | 19   | 16  | 4   | 4   | 24   | 34   | 35   | 34   |
| Th | 15.0 | 10.0 | 10.0 | 6.6  | 8.0 | 0.6 | 2.1 | 15.0 | 12.0 | 13.0 | 12.0 |
| U  | 3.6  | 2.7  | 5.8  | 2.6  | 3.5 | 2.1 | 2.4 | 10.0 | 3.7  | 4.7  | 2.8  |
| Li | 38   | 49   | 32   | 10   | 55  | 11  | 9   | 12   | 57   | 66   | 62   |
| F  | 570  | 330  | 260  | 80   | 269 | 93  | 70  | 70   | 725  | 730  | 705  |
| As | 10.0 | 0.0  | 2.5  | 0.5  | 0.5 | 2.5 | 0.5 | 1.6  | 2.1  | 2.2  | 3.3  |
| Sn | 2    | 3    | 2    | 2    | 10  | 9   | 2   | 2    | 0    | 3    | 9    |
| W  | 0.5  | 0    | 0.5  | 0.5  | 0.5 | 0.5 | 0.5 | 0    | 2    | 3    | 0    |

| Rock Type                      | BMG     | BMG       | BMG       | BMG     | BMG     | BMG       | BMG     | BMG     | BMG      | FGLMG    | FGLMG    |
|--------------------------------|---------|-----------|-----------|---------|---------|-----------|---------|---------|----------|----------|----------|
| Sample                         | A15-118 | A15-120-2 | A15-141-2 | A14-001 | A14-002 | A14-002-1 | A14-003 | A14-008 | A14-1030 | A15-0142 | A14-1040 |
| Major Elements (wt. %)         |         |           |           |         |         |           |         |         |          |          |          |
| SiO <sub>2</sub>               | 67.82   | 67.23     | 67.46     | 69.74   | 68.97   | 69.28     | 69.44   | 69.58   | 70.22    | 75.27    | 76.25    |
| Al <sub>2</sub> O <sub>3</sub> | 15.06   | 15.13     | 15.02     | 14.79   | 15.31   | 14.95     | 14.71   | 14.83   | 14.66    | 13.36    | 13.47    |
| Fe <sub>2</sub> O <sub>3</sub> | 4.35    | 4.71      | 4.30      | 3.70    | 4.00    | 4.02      | 4.47    | 4.07    | 3.55     | 1.47     | 1.20     |
| MgO                            | 1.44    | 1.94      | 1.63      | 1.35    | 1.66    | 1.59      | 1.72    | 1.46    | 1.50     | 0.28     | 0.23     |
| CaO                            | 1.80    | 1.46      | 1.59      | 1.39    | 1.51    | 1.33      | 1.68    | 1.36    | 1.21     | 0.75     | 0.82     |
| Na <sub>2</sub> O              | 3.73    | 3.70      | 3.88      | 3.38    | 2.57    | 3.24      | 2.65    | 3.52    | 3.48     | 3.67     | 3.13     |
| K <sub>2</sub> O               | 3.85    | 3.88      | 4.09      | 4.15    | 4.02    | 4.20      | 3.98    | 4.05    | 4.27     | 4.71     | 4.62     |
| TiO <sub>2</sub>               | 0.59    | 0.62      | 0.55      | 0.45    | 0.51    | 0.51      | 0.58    | 0.50    | 0.43     | 0.06     | 0.06     |
| MnO                            | 0.20    | 0.19      | 0.18      | 0.18    | 0.20    | 0.20      | 0.19    | 0.18    | 0.18     | 0.13     | 0.16     |
| P <sub>2</sub> O <sub>5</sub>  | 0.09    | 0.09      | 0.10      | 0.09    | 0.09    | 0.09      | 0.09    | 0.10    | 0.08     | 0.07     | 0.07     |
| LOI                            | 0.52    | 0.20      | 0.38      | 0.70    | 0.60    | 0.40      | 0.10    | 0.40    | 0.20     | 0.13     | 0.40     |
| Trace Elements (ppm)           |         |           |           |         |         |           |         |         |          |          |          |
| Ba                             | 546     | 642       | 643       | 487     | 565     | 606       | 604     | 595     | 519      | 91       | 72       |
| Rb                             | 158     | 151       | 174       | 187     | 172     | 169       | 173     | 175     | 182      | 259      | 276      |
| Sr                             | 127     | 143       | 126       | 119     | 123     | 127       | 134     | 127     | 112      | 16       | 10       |
| Zr                             | 208     | 219       | 207       | 173     | 196     | 202       | 211     | 194     | 186      | 58       | 40       |
| Nb                             | 13      | 12        | 13        | 12      | 11      | 13        | 15      | 14      | 11       | 7        | 7        |
| V                              | 47      | 51        | 39        | 30      | 33      | 33        | 39      | 30      | 29       | 0        | 0        |
| Y                              | 45      | 48        | 43        | 42      | 38      | 42        | 39      | 37      | 41       | 32       | 20       |
| Ga                             | 17      | 21        | 21        | 16      | 16      | 17        | 18      | 16      | 19       | 16       | 16       |
| Cu                             | 11      | 9         | 6         | 0       | 0       | 0         | 0       | 0       | 0        | 0        | 0        |
| Zn                             | 59      | 70        | 67        | 56      | 61      | 66        | 61      | 54      | 56       | 28       | 25       |
| Hf                             | 7       | 8         | 7         | 7       | 8       | 9         | 8       | 7       | 6        | 2        | 2        |
| Ta                             | 1.4     | 1.3       | 1.3       | 1.5     | 1.2     | 1.2       | 1.1     | 1.2     | 1.0      | 1.7      | 1.3      |
| Sc                             | 12.0    | 12.0      | 11.0      | 7.5     | 9.1     | 10.0      | 9.3     | 9.0     | 7.2      | 3.1      | 3.1      |
| La                             | 35      | 38        | 35        | 31      | 35      | 38        | 34      | 34      | 31       | 6        | 4        |
| Th                             | 13.0    | 13.0      | 13.0      | 13.0    | 13.0    | 14.0      | 12.0    | 12.0    | 12.0     | 5.3      | 3.0      |
| U                              | 3.1     | 4.5       | 3.4       | 3.8     | 3.5     | 3.2       | 3.3     | 3.7     | 3.5      | 3.5      | 1.6      |
| Li                             | 62      | 59        | 63        | 59      | 59      | 53        | 62      | 58      | 62       | 65       | 106      |
| F                              | 650     | 730       | 735       | 695     | 633     | 570       | 698     | 566     | 628      | 270      | 327      |
| As                             | 5.2     | 13.0      | 5.0       | 9.0     | 2.1     | 2.1       | 30.0    | 2.0     | 1.5      | 12.0     | 8.6      |
| Sn                             | 5       | 1         | 0         | 13      | 7       | 2         | 11      | 10      | 5        | 9        | 11       |
| W                              | 0       | 0         | 0         | 0       | 3       | 1         | 1       | 3       | 1        | 3        | 5        |

| Rock Type | FGLMG    | FGLMG    | FGLMG    | FGLMG     | FGLMG    |
|-----------|----------|----------|----------|-----------|----------|
| Sample    | 14-C002A | A14-C004 | A14-1006 | 14-1006-1 | A14-1007 |

## Major Elements (wt. %)

|                                |       |       |       |       |       |
|--------------------------------|-------|-------|-------|-------|-------|
| SiO <sub>2</sub>               | 75.64 | 76.10 | 75.38 | 75.23 | 75.16 |
| Al <sub>2</sub> O <sub>3</sub> | 13.62 | 13.74 | 13.72 | 13.53 | 13.76 |
| Fe <sub>2</sub> O <sub>3</sub> | 1.30  | 0.98  | 1.15  | 1.30  | 1.18  |
| MgO                            | 0.24  | 0.37  | 0.28  | 0.22  | 0.25  |
| CaO                            | 0.77  | 0.87  | 0.73  | 0.87  | 0.79  |
| Na <sub>2</sub> O              | 3.80  | 3.59  | 4.31  | 4.09  | 3.82  |
| K <sub>2</sub> O               | 4.22  | 3.54  | 4.19  | 4.54  | 4.48  |
| TiO <sub>2</sub>               | 0.03  | 0.04  | 0.03  | 0.04  | 0.04  |
| MnO                            | 0.14  | 0.14  | 0.16  | 0.15  | 0.12  |
| P <sub>2</sub> O <sub>5</sub>  | 0.06  | 0.02  | 0.05  | 0.07  | 0.08  |
| LOI                            | 0.40  | 0.40  | 0.40  | 0.40  | 0.80  |

## Trace Elements (ppm)

|    |     |      |      |     |      |
|----|-----|------|------|-----|------|
| Ba | 36  | 67   | 123  | 23  | 22   |
| Rb | 288 | 213  | 286  | 307 | 283  |
| Sr | 13  | 39   | 20   | 12  | 11   |
| Zr | 39  | 46   | 45   | 44  | 43   |
| Nb | 5   | 7    | 6    | 7   | 8    |
| V  | 0   | 16   | 0    | 0   | 0    |
| Y  | 24  | 20   | 20   | 26  | 23   |
| Ga | 16  | 19   | 18   | 16  | 18   |
| Cu | 0   | 52   | 0    | 0   | 0    |
| Zn | 51  | 25   | 36   | 43  | 21   |
| Hf | 2   | 1    | 2    | 2   | 2    |
| Ta | 1.7 | 1.7  | 2.2  | 1.8 | 1.8  |
| Sc | 2.4 | 3.5  | 2.9  | 3.1 | 3.2  |
| La | 4   | 5    | 3    | 4   | 4    |
| Th | 3.9 | 4.2  | 4.3  | 4.3 | 4.2  |
| U  | 7.8 | 13.0 | 4.5  | 4.8 | 4.8  |
| Li | 21  | 19   | 21   | 57  | 41   |
| F  | 63  | 177  | 160  | 317 | 120  |
| As | 8.4 | 22.0 | 17.0 | 7.3 | 17.0 |
| Sn | 0   | 0    | 0    | 0   | 0    |
| W  | 3   | 8    | 11   | 4   | 1    |

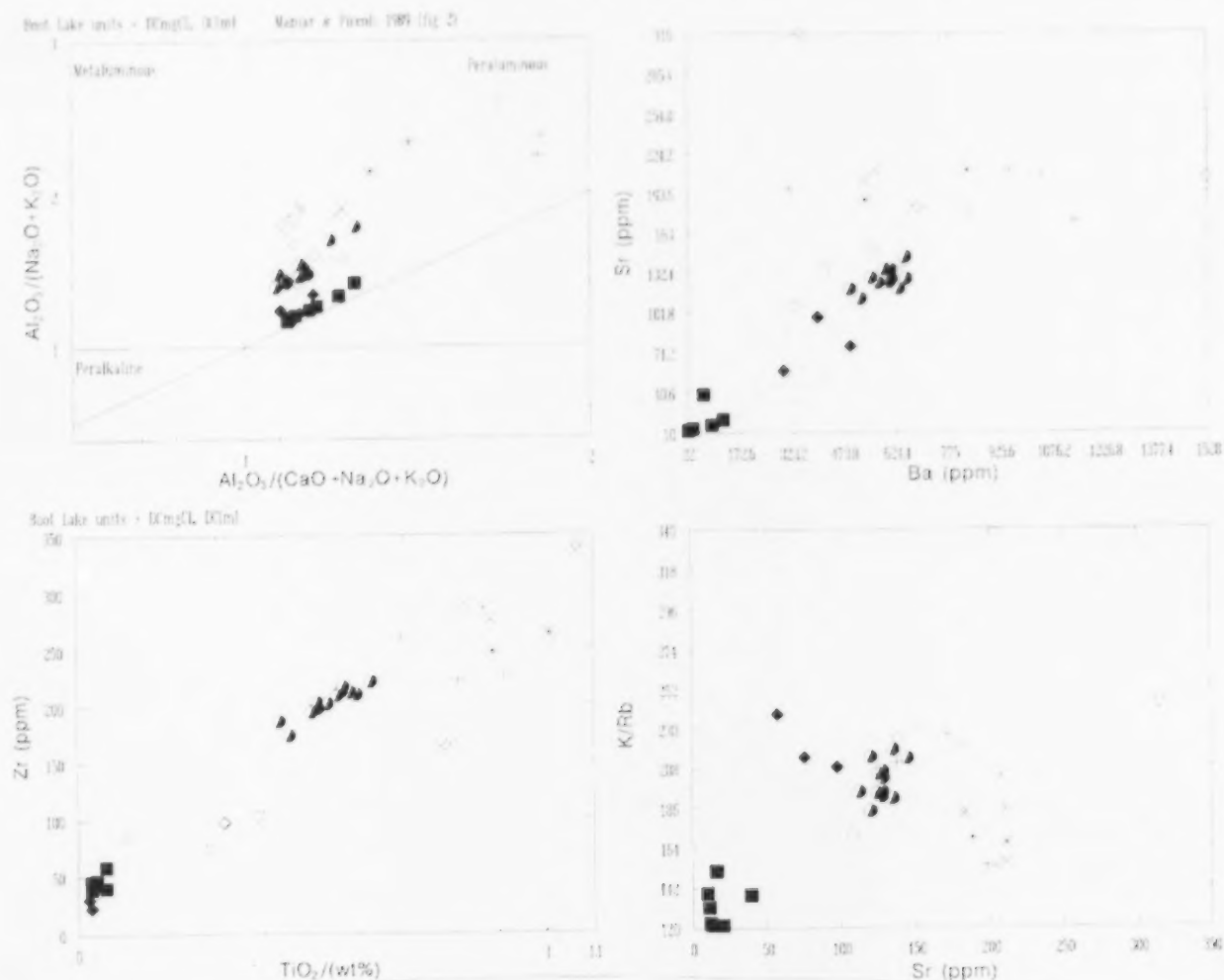


Figure 5.18 Bivariate plots for the Boot Lake granodiorite/mafic porphyry unit. See text for discussion.

of metasedimentary rocks. Rocks designated "biotite-rich granodiorite" are primarily fine- to medium-grained with slightly porphyritic texture with minor modal amounts of quartz and feldspar phenocrysts. These rocks do not have a close spatial association with metasedimentary rocks and have fewer xenoliths than the two previous groups. Several isolated outcrops of muscovite-biotite monzogranite were noted within the Boot Lake unit and a garnet-bearing leucogranite dyke was also noted in the eastern end of the unit. The exact relationship between these rocks and the rest of the unit is unclear, as indicated in Chapter 3.

The sequence of hybrid rocks, garnet-bearing mafic porphyry and biotite-rich granodiorite is marked by large ranges in major element concentrations including 60.85-65.96%  $\text{SiO}_2$ ; 4.89-7.64%  $\text{Fe}_2\text{O}_3$ ; 1.12-3.21%  $\text{CaO}$ ; 0.96-3.07%  $\text{MgO}$ ; 0.68-1.06%  $\text{TiO}_2$ . Samples with the highest  $\text{SiO}_2$  and the lowest  $\text{Fe}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$  and  $\text{TiO}_2$  closely resemble average biotite granodiorite of the entire batholith, whereas other samples have the lowest  $\text{SiO}_2$  and highest concentrations of ferromagnesian and some "compatible" elements (1101 ppm Ba; 209 ppm Sr; 338 ppm Zr; 26.6 ppm Sc; 65 ppm La) in the entire batholith.

Three possible origins for the Boot Lake mafic porphyry rocks, based primarily on field relations, include: 1) contamination of granodiorite magma via extensive assimilation of Meguma Group metasedimentary rocks; 2) sidewall fractional crystallization and/or cumulate development at margins of granodiorite magma; and 3) partial melting of Meguma Group metasedimentary rocks. The viability of each of these processes can be evaluated using the above geochemical data.

A Shand-type plot (Maniar and Piccoli, 1989) for the Boot Lake data is presented in Figure 5.18 (symbols on pg. 132). Hybrid and garnet-bearing mafic porphyry rocks have very high A/CNK values that are among the highest values reported for the batholith. Highly peraluminous compositions are consistent with a large degree of assimilation of aluminous sedimentary rocks. In contrast, the very high concentrations of some "compatible" elements, as outlined above, are difficult to reconcile by a process of assimilation because the levels of these elements in Halifax Formation slates are in fact lower than the average Cloud Lake biotite monzogranite (pers. comm. A.K. Chatterjee, 1993). Therefore extensive assimilation of Meguma Group rocks by the Cloud Lake magma would actually "dilute" the levels of these elements in the resulting rocks.

MacDonald and Horne (1988) evoked a process of sidewall fractional crystallization to

explain the smooth compositional "trends" and formation of biotite granodiorite along the margins of the Halifax Pluton. Bivariate plots of Sr versus Ba, Zr versus  $\text{TiO}_2$  and K/Rb versus Sr for the Boot Lake and related samples from Table 5.7 are given in Figures 5.18b to d. It is apparent in all plots that the Cloud Lake biotite monzogranite and Inglisville fine-grained leucomonzogranite form a cohesive, and continuous, sequence whereas the rocks of the Boot Lake unit plot well off this trend, in contrast to the data of MacDonald and Horne (1988). However, Corey (1992) has documented biotite + apatite- and plagioclase-rich cumulate phases within the Big Indian pluton. Corey also described biotite-rich granodiorite rocks that were interpreted as forming from "cumulate" processes. Geochemical analyses from this granodiorite (unpubl. data M.C. Corey) indicated values of most major and trace elements (e.g. 4.89%  $\text{Fe}_2\text{O}_3$ ; 3.29% CaO; 1045 ppm Ba; 174 ppm Rb; 209 ppm Sr; 224 ppm Zr) that are remarkably similar to the biotite-rich hybrid, mafic porphyry and granodiorite rocks of the Boot Lake body. This observation suggests that cumulate processes could be responsible, at least in part, for the formation of the Boot Lake mafic porphyry rocks.

It is difficult to estimate the plausibility of partial melting of Meguma Group rocks for the formation of Boot Lake rocks using only the major and trace element geochemical data. Certainly if the hybrid and mafic porphyry rocks represent melanosomes from partially developed migmatites, the high concentrations of "compatible" elements can be explained by the preferential accumulation of ferromagnesian minerals (pers. comm. A.K. Chatterjee, 1993). A more definitive evaluation would require radiogenic and stable isotopic data which would establish the relative contribution of both granite and metasediment sources.



#### 5.4 Summary

This study represents the most comprehensive lithogeochemical study of the South Mountain Batholith to date. The suite of 597 samples characterize the entire range of compositions from the least evolved biotite granodiorite and mafic porphyry to the most evolved leucogranite and hydrothermally altered rocks associated with post-magmatic mineralization. In addition, the geographic distribution of samples provides, for the first time, insight into the internal geochemical variation of plutons.

Perhaps the most striking feature of the geochemistry of the batholith is the overall similarity in composition throughout the batholith. All rocks are peraluminous (i.e. molecular  $\text{Al}_2\text{O}_3/(\text{CaO}+\text{K}_2\text{O}+\text{Na}_2\text{O}) > 1$ ) and have relatively high  $\text{SiO}_2$  and low CaO with ranges from 67.12 % (SD-1.73) and 1.94 % (SD-0.46), respectively, in granodiorite to 73.62 % (SD-0.89) and 0.39 (SD-0.14), respectively, in leucogranite rocks. The major element chemistry and normative composition of the major rock types indicates a progression from least evolved biotite granodiorite to most evolved leucogranite that reflects the petrographic features of the different rock types. This sequence is marked by systematic decreases in  $\text{TiO}_2$ ,  $\text{Fe}_2\text{O}_3$ , MnO, MgO, CaO, K/Rb and normative anorthite, enstatite, ilmenite, hematite, rutile and colour index and increases in  $\text{SiO}_2$ , normative quartz, A/CNK and Thornton-Tuttle differentiation index. The concentration of  $\text{P}_2\text{O}_5$  is generally consistent from granodiorite to fine-grained leucomonzogranite with a sudden increase in leucogranite units. This sequence is also marked by systematic decreases in several compatible trace elements (i.e. Ba, Sr, Zr, V, Hf, Sc and La) and increases in several incompatible trace elements (i.e. Rb, Ta, U, Li, F, Sn and W).

Despite the overall compositional similarities throughout the batholith, it is possible to

distinguish among individual plutons as seen in the Harker variation diagrams of Figures 5.1 and 5.2 and discussed in Section 5.2.3. It is apparent from these plots that the overall concentrations of many elements, and in some cases the slopes of regression lines, vary significantly among the Stage I and II plutons. These data indicate the batholith formed by the coalescence of discrete plutons, in contrast to earlier studies that proposed the entire batholith formed from a single parental magma.

Perhaps one of the most important implications of the geochemical data is the delineation of cryptic normal and reverse compositional zoning in both Stage I and II plutons (MacDonald and Horne, 1988; Horne et al., 1989; MacDonald et al., 1992). The establishment of zoning patterns in the batholith will provide a framework for future work, including mineral exploration.

Geochemical data have also revealed large geochemical ranges in some units, including some with somewhat restricted modal mineralogical variation (e.g. Davis Lake Leucomonzogranite). Large compositional variation in the mafic porphyry bodies may reflect varying degrees of assimilation or wall-rock interaction as evidenced by the very high A/CNK values. Lithogeochemical composition of aplite dykes may also vary significantly as seen in a single outcrop in the Halifax Pluton where dyke rock compositions approximated the entire range for the rest of the batholith. Cryptic REE variations in several rock suites from the batholith merit further work.

In short, the geochemical data generated during the SMB project has yielded new insights into the composition of the batholith and provides an excellent framework for future work.

## Chapter 6

### STRUCTURE AND EMPLACEMENT

#### 6.1 Introduction

Several previous workers have noted the presence of localized and, to a lesser degree, regional planar features within the batholith (McKenzie, 1974; Smitheringale, 1973) and other granitoids of the Meguma Zone (MacDonald, 1981). However, most previous studies have concluded that the South Mountain Batholith is a massive, post-tectonic body that was largely unaffected by regional deformation (Taylor, 1969; Cormier and Smith, 1973; Smith, 1974; McKenzie and Clarke, 1975; Clarke and Chatterjee, 1988). The following sections present information that indicates structure played an important role in the evolution of the batholith.

Structural information was routinely collected throughout the batholith during regional mapping. Data included the orientation, size, spacing and type(s) of dykes, veins, joints, shear zones and faults. The presence and style of mineralization and hydrothermal alteration along these planar features was also noted. In addition, the orientation and degree of development of primary flow features, such as parallel mineral alignment and schlieren banding, were noted. This information was graphically portrayed on the fourteen 1:50,000 scale geological maps (see Fig. 2.1 for index). Structural data were compiled and interpreted by Horne et al. (1988, 1992) and many of the salient aspects of their work are presented in the following sections.

#### 6.2 Primary Flow Features

Primary flow features in the batholith (Fig. 6.1) consist of megacryst alignment (Plate 6.1), schlieren banding (Plate 6.2) and biotite foliation (Plate 6.3). Megacryst alignment is the most abundant feature and consists of parallel alignment of tabular feldspar (mainly alkali feldspar) megacrysts. Elongate or tabular xenoliths are commonly oriented with long axes parallel to megacryst alignment. The smooth glaciated nature of most outcrop impedes the determination of three dimensional orientation, however, where measured, orientations were predominantly steeply-dipping. Characteristically, megacryst alignment varies slightly in orientation over single outcrops, although "swirling" patterns were also noted throughout the batholith. Measurements were only collected when a distinct preferred orientation over most of an exposed outcrop area

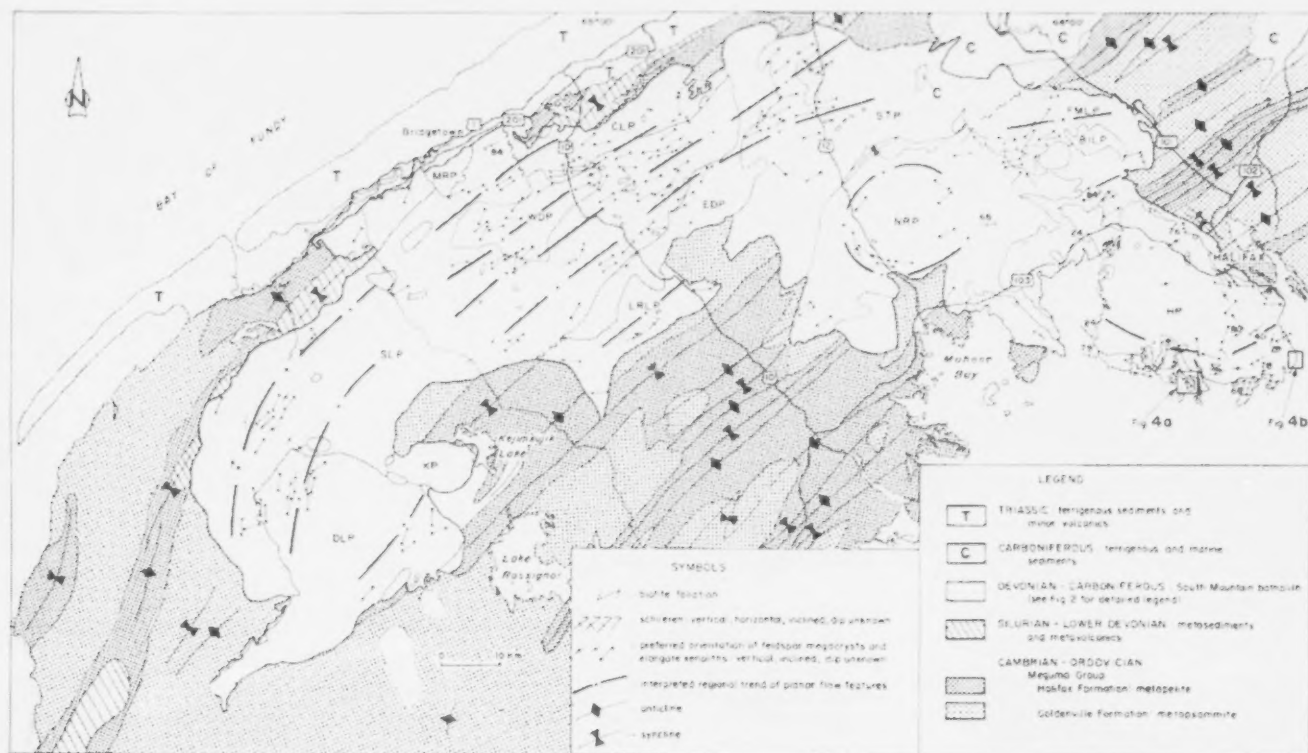


**Figure 6.1** Primary flow features including megacryst alignment, schlieren and biotite foliation in the South Mountain Batholith (after Horne et al., 1992).

was evident.

Most Stage I plutons, particularly in the western portion of the batholith, and the Davis Lake and West Dalhousie Stage II plutons display weakly- to moderately-developed NE-trending megacryst alignment. Orientations in the SW part of the batholith are primarily N to NNE. These features parallel regional structural trends in the country rocks and have been interpreted as reflecting regional Late Acadian stress (Horne et al., 1988, 1992) during initial stages of magma emplacement. These features may also reflect stresses related to the emplacement of the various plutons, for example "ballooning" may explain the N-trending flow features in parts of the Scrag Lake and Davis Lake plutons (Horne et al., 1992).

The Halifax and New Ross Stage II plutons display weakly-developed circular primary flow features (Fig. 6.1) that sharply contrast with the rest of the batholith. These patterns mainly parallel the margins of the plutons, particularly in the Halifax Pluton, and are provisionally interpreted as reflecting internal stress and/or primary flow/shear within magma that was related

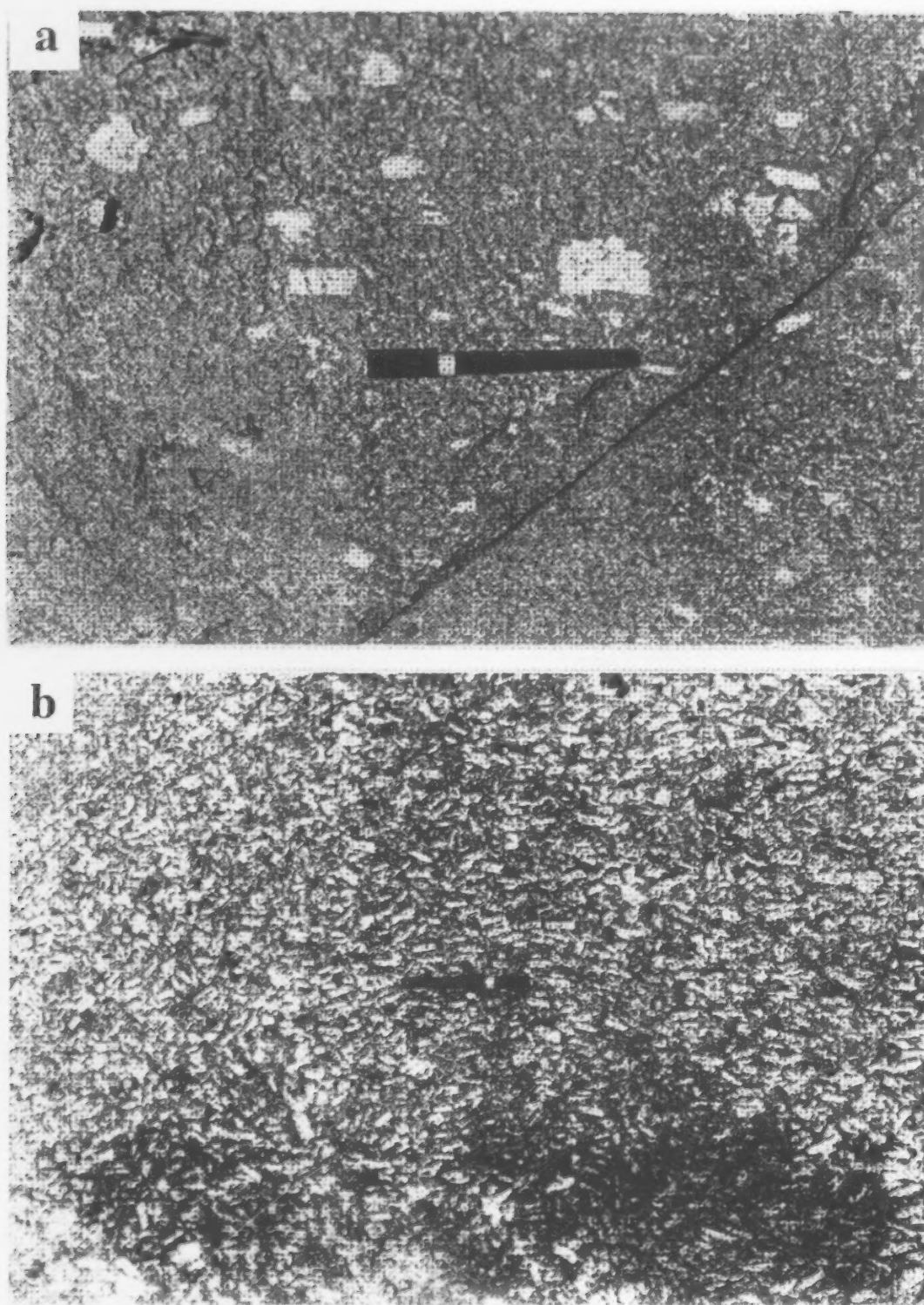


Plate 6.1 a) Parallel alignment of alkali feldspar megacrysts in the Cloud Lake biotite monzogranite. Preferred orientation, indicated by pen, is defined by euhedral megacrysts ranging from approximately 1.5- >5 cm in length; b) Erratic primary flow features in the West Dalhousie coarse-grained leucomonzogranite (MacDonald and Ham, 1992). Note the erratic orientations and the uniform size of alkali feldspar megacrysts (approximately 1 x 2.5 cm).



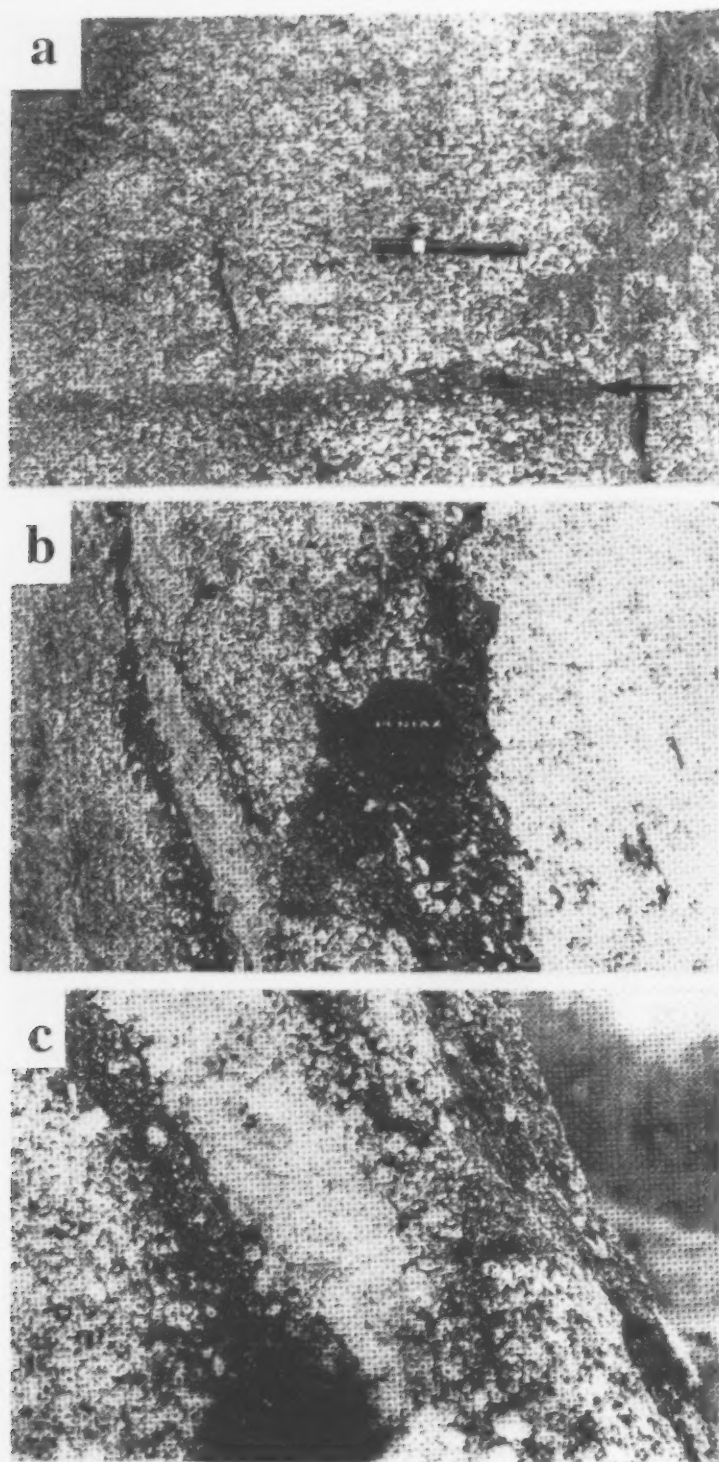


**Plate 6.2** Schlieren banding in: a) Scrag Lake biotite monzogranite (NTS sheet 21A/15; MacDonald and Ham, 1992). Banding is defined by high modal amounts of biotite in gradational contact with megacrystic monzogranite. Banding parallels weakly-developed megacryst alignment; b) biotite granodiorite of the Halifax Pluton. Outcrop is located along the Bicentennial highway, near the contact with the transition zone of the Meguma Group country rocks. Note the banding consists of alternating mafic (biotite  $\pm$  garnet) and quartzo-feldspathic layers in contrast to the banding in a); c) close-up of schlieren in b).



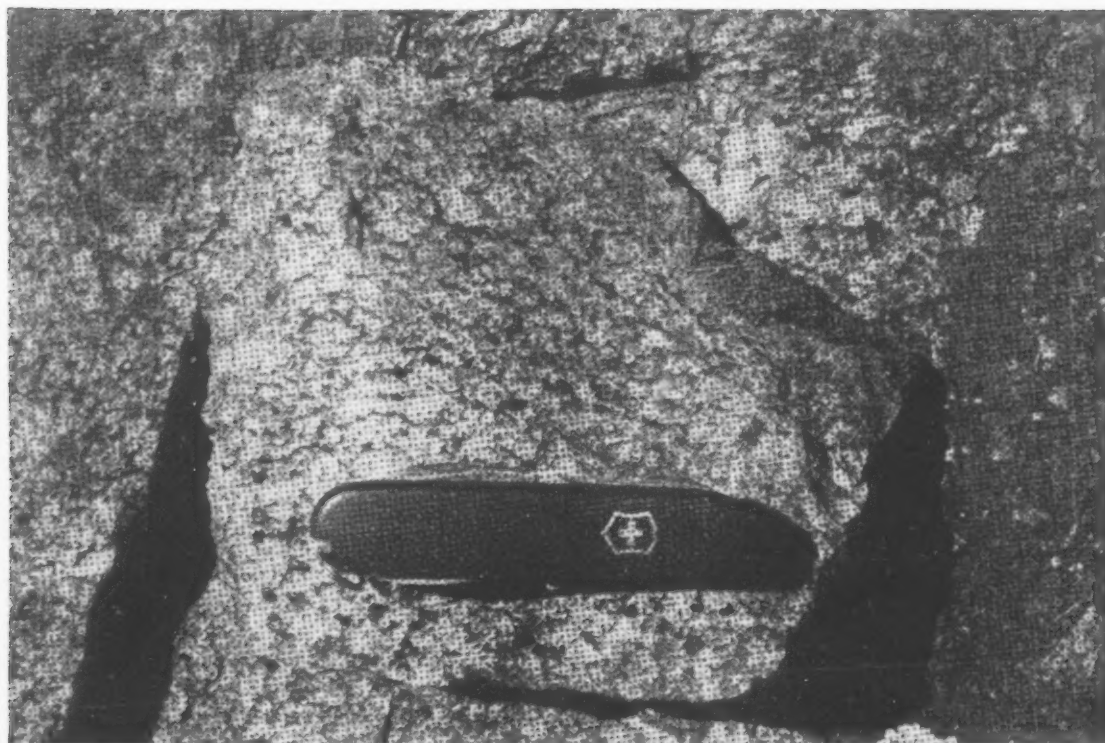


**Plate 6.3** Biotite foliation with feldspar augen in the Cloud Lake monzogranite (MacDonald and Ham, 1992). (foliation is sub-parallel to pocket knife).

to the emplacement and crystallization of these plutons in accord with the conclusions of Abbott (1989) and Horne et al. (1992).

The East Dalhousie, Morse Road, Kejimikujik and Big Indian Stage II Plutons either lack primary flow features entirely or have highly erratic outcrop-scale megacryst alignments with no preferred direction. Accordingly there are no measurements for these plutons in Figure 6.1.

Schlieren, which consist of biotite-rich bands that commonly have medium-grained equigranular or seriate texture, were observed in some outcrops throughout the batholith. Most schlieren consist of "wispy" bands that rarely exceed several metres in length or width. Schlieren banding commonly is oriented parallel to other primary flow features including megacryst alignment and elongated xenoliths, as exposed in several outcrop along the southern margin of the Halifax Pluton.

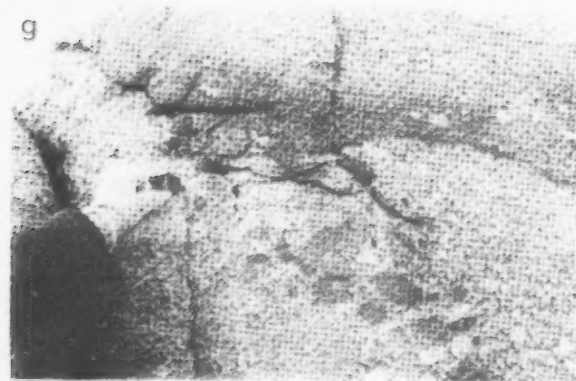
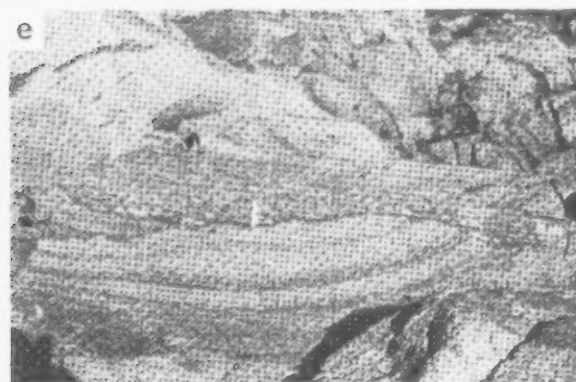
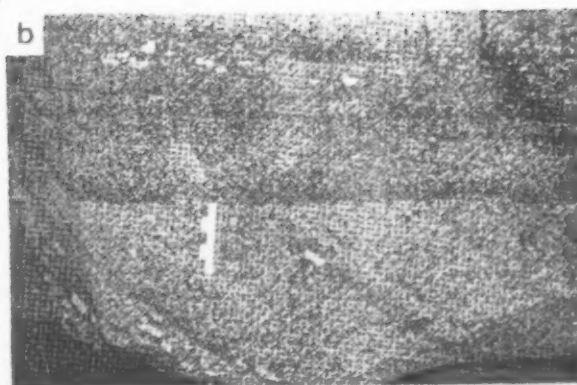
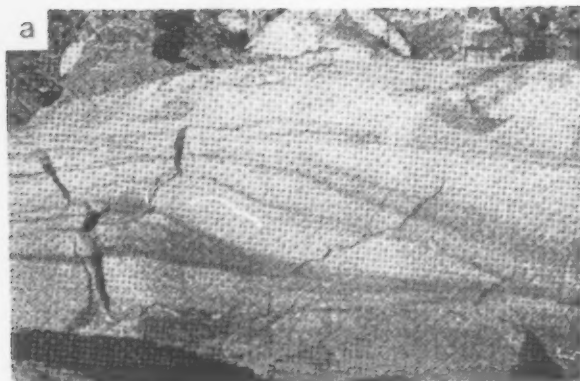
A rare occurrence of well-developed rhythmic layering, with cross- and graded-bedding

(Plate 6.4 a to h), is exposed at Chebucto Head in the Halifax Pluton (Smith, 1975; Clarke and Muecke, 1980; Abbott, 1989). The "exotic layering" is accompanied by cross-cutting dykes containing alkali feldspar megacrysts  $\pm$  metasedimentary xenoliths. Several contrasting models for the formation of this banding have been proposed, however, it is generally believed that formation of these features resulted from flow and/or shear within a crystal "mush" with flow segregation or filtering of fine- and coarse-grained components of a partially crystallized monzogranite magma. Clarke and Muecke (1980) concluded that the megacryst- and xenolith-rich dykes (termed 'log-jam' dykes), oriented obliquely to the layered sequence, represent 'feeders' for the non-megacrystic layers and were caused by influx of biotite monzogranite melt into cracks in partially solidified rock. Similar features were observed in rare outcrop throughout the batholith but nowhere was the layering as well exposed as at Chebucto Head.

Biotite foliation is restricted to a band (approx. 1.5 x 6 km) along the southern margin of the Cloud Lake Pluton, adjacent to the West Dalhousie Pluton (Fig. 6.1). Foliation of platy biotite crystals may be accompanied by alkali feldspar and plagioclase augen, encircled by biotite, and elongate xenoliths with long axes parallel to foliation (McKenzie, 1974; MacDonald and Ham, 1992). Biotite foliation ranges from 070° to 088° and thus is sub-parallel to regional megacryst alignment in the batholith and structural trends in the country rocks. The zone of biotite foliation is gradational with non-foliated Cloud Lake monzogranite to the north and is sharply truncated by the West Dalhousie Stage II Pluton. This zone of biotite foliation has been interpreted as reflecting localized stress on the Cloud Lake monzogranite during crystallization. However it is unclear whether the stress is regional tectonic or related to internal stress (e.g. "ballooning") related to emplacement of the Cloud Lake and/or West Dalhousie plutons (MacDonald and Ham, 1992; Horne et al., 1992).

Local "pods" of alkali feldspar megacrysts and xenoliths (Plate 6.5), interpreted to represent primary flow concentration features in partially crystallized granitoid magmas, are

**Plate 6.4** (Following page) Rhythmic layering in the Harrietsfield monzogranite at Chebucto Head (MacDonald and Horne, 1987; photos courtesy of Barrie Clarke): a) to f) photos showing complex inter-layering of medium-grained equigranular (seriate) textured granite with biotite-rich and biotite-poor bands defining complex layering sequence. Megacrysts of alkali feldspar are restricted to specific layers in sequence and are predominantly oriented parallel to layering. Cross bedding and scour-and-fill structures are evident in several photos; g) and h) 'log-jam' dykes with high modal proportion of alkali feldspar megacrysts and metasedimentary xenoliths that cross-cut layering (e.g. in h). Clarke and Muecke interpreted these 'dykes' to represent feeder for the equigranular layers in the sequence.



locally developed in many megacrystic rock units of the batholith (e.g. Harrietsfield monzogranite, MacDonald and Horne, 1987; Scrag Lake monzogranite, MacDonald and Ham, 1992). These features are interpreted as resulting from flow segregation, possibly associated with convection in granitic melts. The pods have irregular, often circular, shapes that do not have a preferred orientation and hence are not portrayed in Figure 6.1. However, their occurrence is depicted graphically on the fourteen 1:50,000 scale geological maps.

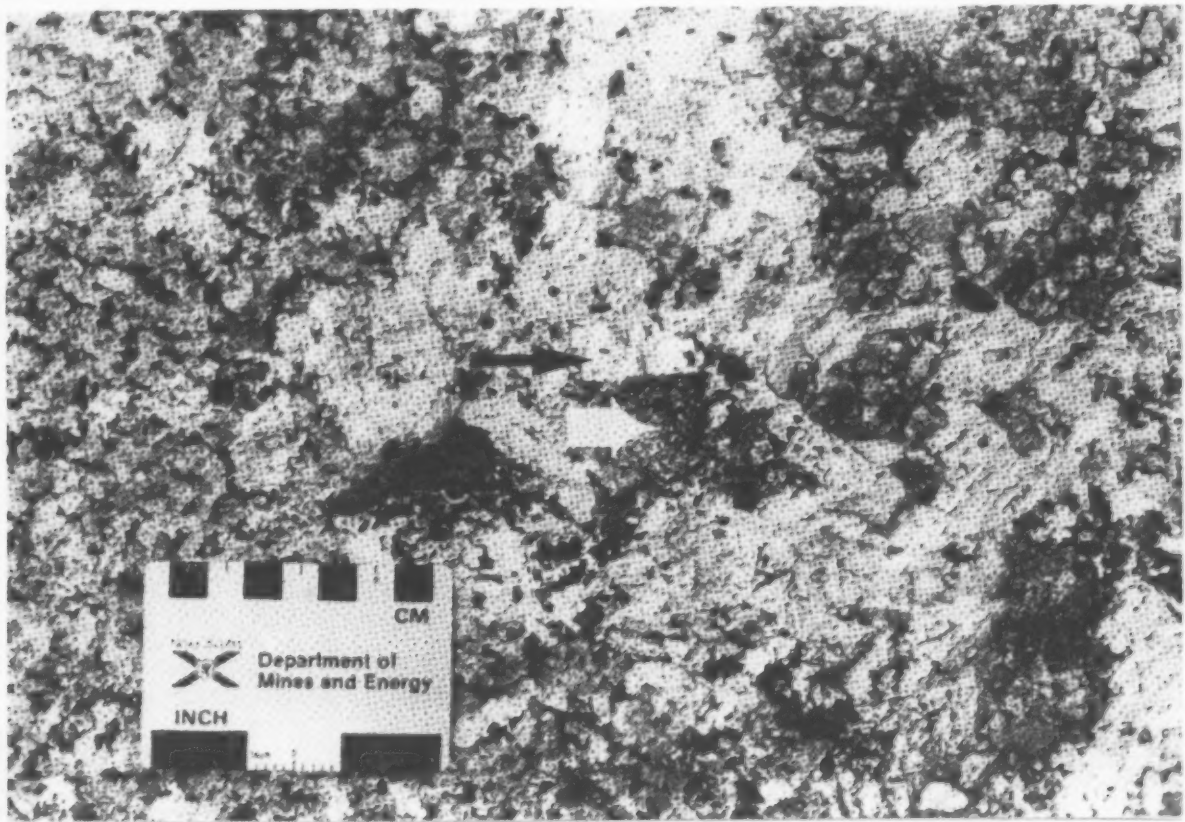


**Plate 6.5** Alkali feldspar megacryst/xenolith pod in the Scrag Lake biotite monzogranite (NTS sheet 21A/15; MacDonald and Ham, 1992). Black arrow indicates euhedral K-spar megacryst. White arrow points to partially assimilated metasedimentary(?) xenolith. Note megacrystic texture characteristic of this unit is shown in lower left corner of photo. Pod has irregular outline, is gradational with megacrystic rocks and is interpreted as flow concentration in crystal/liquid "mush", possibly by local-scale convection.

### 6.3 Joints, Dykes and Veins

Horne et al. (1988; 1992) compiled structural data for joints, dykes and veins from approximately 2000 outcrops that were examined in detail during mapping. They prepared contoured density stereoplots for each feature in several geographic regions of the batholith and for selected Stage II plutons.



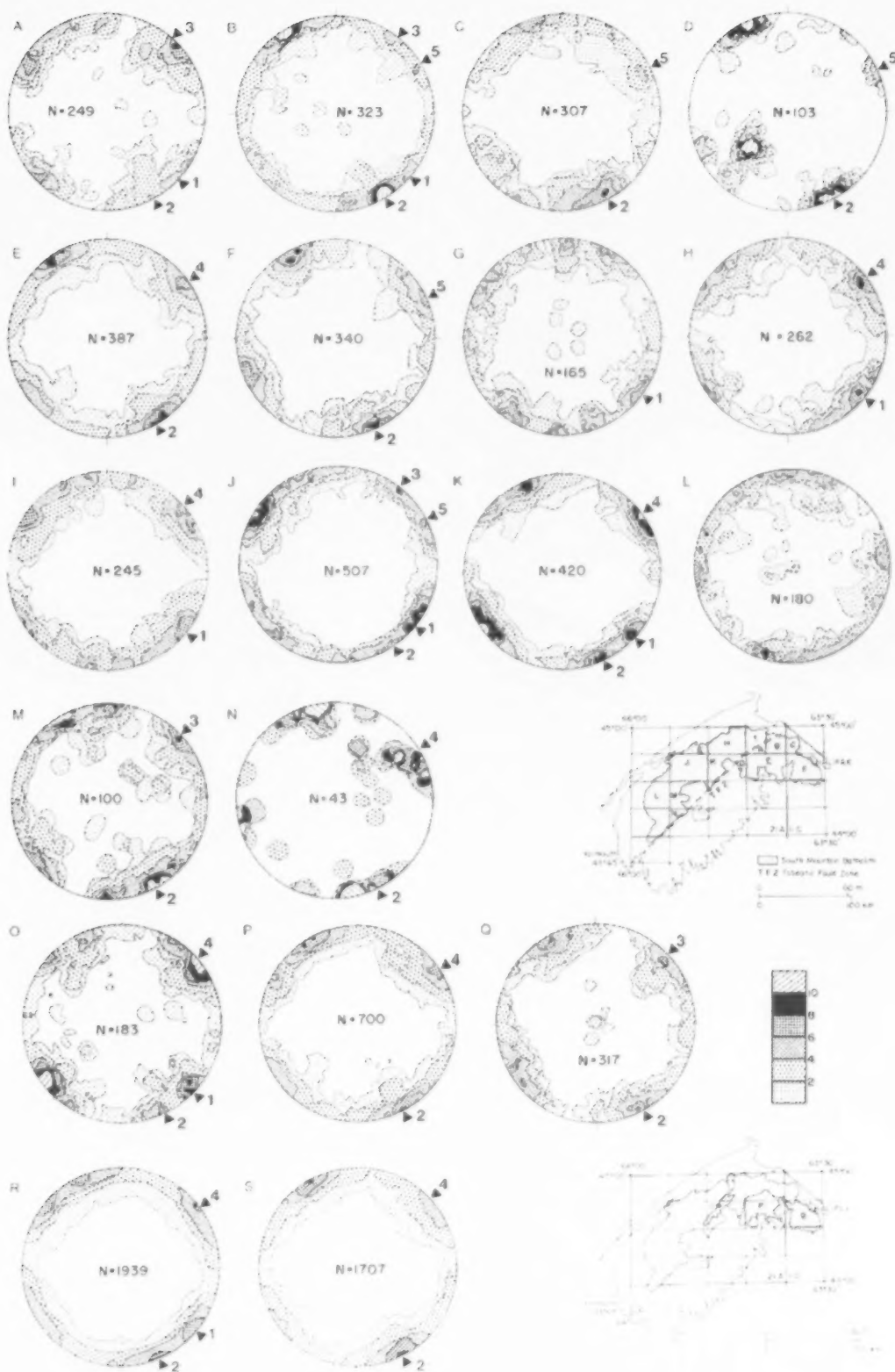


**Figure 6.2** (Previous page) Contoured density plots of poles to joints (in 1% area) in parts of the South Mountain Batholith (after Horne et al., 1992). Stereoplots A to N are from full or portions of NTS map sheets in upper index map. Stereoplots O, P and Q are from the East Dalhousie, New Ross and Halifax Plutons respectively (see lower index map).

Stereoplots for poles to **joints** from the various map sheets and the East Dalhousie, New Ross and Halifax Stage II plutons are presented in Figure 6.2. Horne et al. (1992) concluded that "a repetitive, roughly orthogonal pattern, defined by maxima, or set of sub-maxima, representing steeply dipping NE- and NW-trending joints dominate the stereoplots of nearly all data sets." They noted that three sub-maxima (trends 3,4,5) define the NW-trending joint sets whereas two sub-maxima (trends 1,2) demarcate the NE-trending joint sets. Northwest-trending joints are, for the most part, straight-sided, evenly-spaced and form the dominant joints in most outcrop throughout the batholith (Plate 6.6a). Some joints have hydrothermal coatings (e.g. muscovite greisen) or host greisen-bordered quartz veins and may contain polymetallic Sn-W-Mo mineralization (see below and discussion in Chapter 9). In contrast, NE-trending joints are poorly developed and have curvilinear shape with irregular spacing (Plate 6.6b). The NE-trending joints commonly form narrow zones of closely-spaced fracture cleavage with variable associated hematization and/or chloritization that may host Mn or U mineralization (discussed in Chapter 9).

A compilation map showing the distribution and orientation of **granite dykes** (N=811) and stereoplots for poles to dykes for the portions of the batholith to the west and east of the proposed Tobeatic Fault Zone (Giles, 1985) are given in Figure 3.3. Dyke rock types mainly include aplite, fine-grained equigranular or porphyritic textured leucomonzogranite, pegmatite and composite or inter-banded aplite-pegmatite. Geological descriptions for dyke rocks are given above in Section 3.4. Most dykes in the entire batholith are steeply-dipping ( $>45^\circ$ ), which may be an artifact of the low-lying glaciated nature of most outcrop investigated, which decreases the likelihood of shallow-dipping dykes being exposed. The dykes from the western part of the batholith (Fig. 3.3a) are primarily oriented to the NW and correspond to joint trends 4 and 5. The dykes in the eastern part of the batholith display much more scatter (Fig. 3.3b). Horne et al. (1992) noted that dykes may locally define systematic radial or concentric map patterns that they tentatively interpreted to result from stresses associated with intrusion.



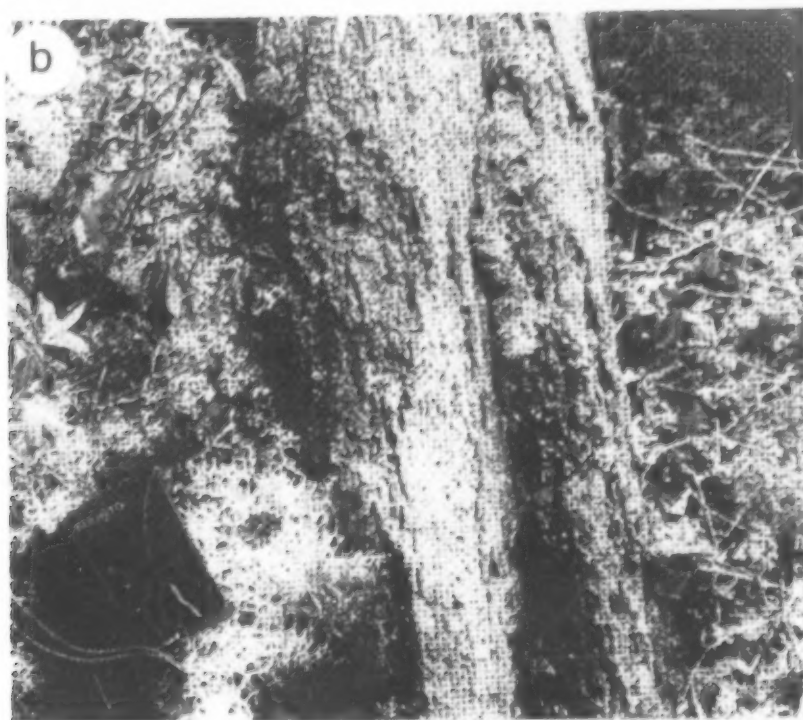
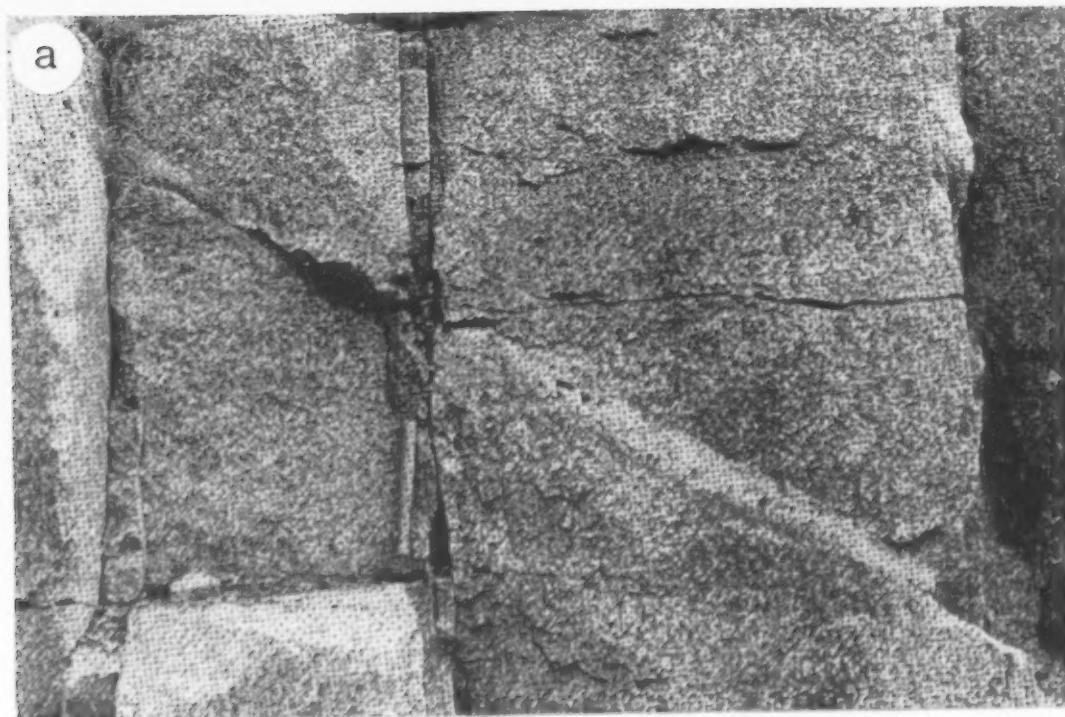


Plate 6.6 a) Outcrop of Sandy Lake biotite monzogranite from the Halifax Pluton (MacDonald and Horne, 1987) with typical straight-sided NW-trending (trend 4) joints with consistent spacing (1-2m wide). Note the presence of sub-horizontal, slightly curvilinear joints and a moderately-dipping aplite dyke. b) outcrop of biotite monzogranite (?) with closely-spaced NE-trending (trend 1?) fracture joints.

The distribution of **quartz veins** from the entire batholith (N=441) along with stereoplots for poles to veins from the eastern and western portions of the batholith are presented in Figure 6.3. Quartz veins mainly range in width from 1-10 cm, although larger veins to 1-2 m have been observed, and may occur in sheeted vein sets. Veins are dominantly NW-trending with steep dips and mainly coincide with the orientation of joint trend 4. Vein orientations appear to be unaffected by such factors as proximity to granite/granite or granite/metasediment contacts and do not define localized patterns as noted for the granite dykes.

#### 6.4 Faults

The distribution of major fault and shear zones is given in Figure 6.4. Most of these structures were unrecognized prior to recent mapping (Horne et al., 1988, 1992; MacDonald et al., 1992; and references therein). Brittle faults predominate in most areas in the batholith and are characterized by heterogeneous deformation consisting of narrow breccia, microbreccia and cataclasite zones (generally  $\leq 1$ m wide; Plate 6.7a) within wider (10->100m wide) moderately deformed zones containing slickensided shears (Plate 6.7b) or brittle fractures (Plate 6.7c). Most brittle faults have moderate to intense hematization and chloritization that may be accompanied by slight to intense silicification (Plate 6.7d). For example the Roxbury Brook Fault (RBF in Figure 6.4) is characterized by intensely brecciated, silicified and hematized zones with relict feldspar grains that are variably replaced by quartz (MacDonald and Ham, 1994). These zones have been previously termed "jasper breccia" by Rogers (1981) and elsewhere as "breccia zones" by Smitheringale (1973). The superposition of brecciation and alteration indicates multiple stages of deformation and fluid influx along the Roxbury Brook Fault that is typical of many brittle faults elsewhere in the batholith. Ductile shear zones are restricted to the southwestern portion of the Davis Lake Pluton. Horne et al. (1992) noted that these faults "are characterized by variably penetrative brittle-ductile to ductile deformational textures, including C-S fabrics," (Plate 6.7e) "mylonite, blastomylonite, ultramylonite and rare rodded mylonite gneiss" (Plate 6.7f). Some shear zones show late brittle deformation and associated silicification.

The absence of significant displacement of granitic map units coupled with the predominance of vertical or steeply-dipping slickensides along NE-trending faults indicate that displacement was primarily vertical. Sense of movement is indicated by the Riedel shear geometry (R' and P) of trends 1 and 2 joints that is consistent with dextral displacement along NE-trending

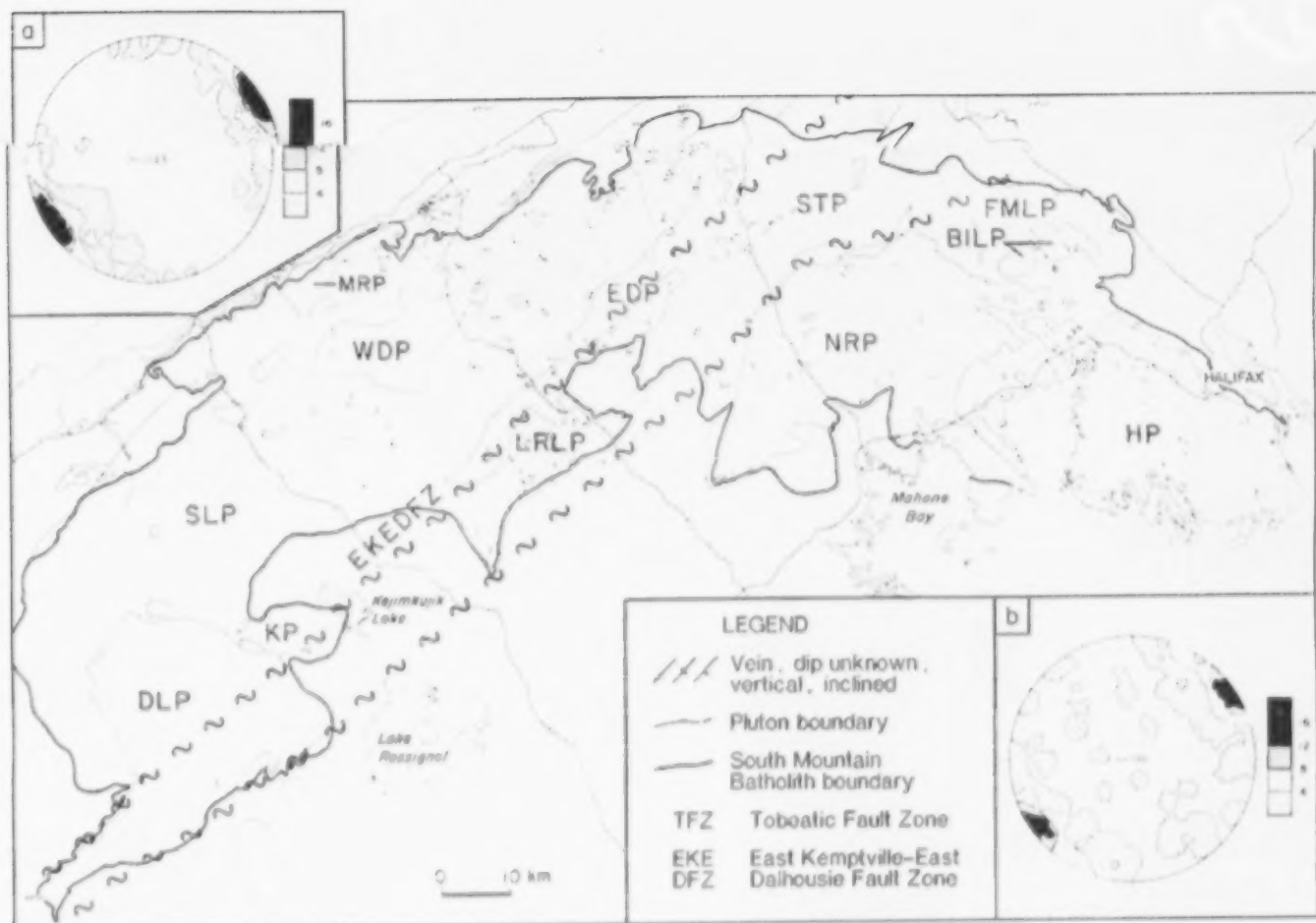


**Figure 6.3** Map showing the distribution and orientation of quartz veins in the South Mountain Batholith (after Horne et al., 1992). Contoured density plots of poles to veins (in 1% area) are for the areas of the batholith to the west (a) and east (b) of the proposed Tobeatic Fault Zone of Giles (1985). Pluton abbreviations are given in Figure 6.4.

faults (Horne et al., 1992). Similarly, C-S fabrics in the East Kemptville shear zone were interpreted by (Kontak et al., 1986) to represent dextral shear. In contrast, recent mapping at the East Kemptville Mine (Halter et al., 1993) has revealed the presence of kinematic indicators including en-echelon quartz-sulphide veins and sub-vertical fault/shear zones that signify vertical displacement along the East Kemptville shear zone during the late paragenetic stages of mineralization.

Sinistral displacement along the NW-trending Herring Cove fault and Roxbury Brook

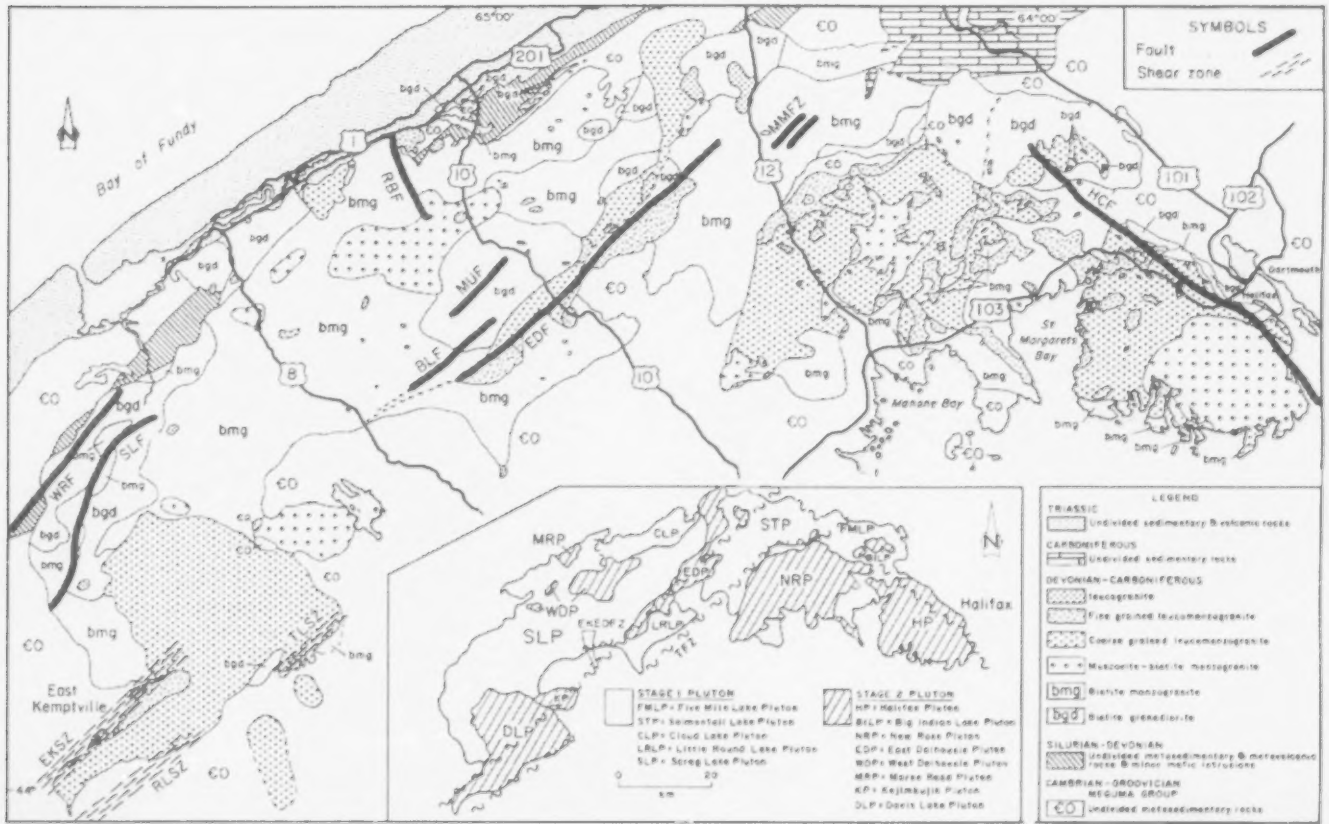


**Figure 6.4** Geological map of the South Mountain Batholith showing the location of the major fault and shear zones (modified after Horne et al., 1992). Faults include: BLF - Beaver Lake fault; EDF - East Dalhousie fault; EKFDFZ - East Kemptville-East Dalhousie fault zone; EKSZ - East Kemptville shear zone; HCF - Herring Cove fault; MMFZ - Manganese Mines fault zone; MUF - Molly Upsim fault; RBF - Roxbury Brook fault; RLSZ - Rushmere Lake shear zone; SLF - Sissiboo Lake fault; TFZ - Tobeatic fault zone; TLSZ - Tobeatic Lake shear zone; WRF - Wallace River fault.

fault is indicated by the apparent displacement of granite map units in the Halifax Pluton and the margin of the West Dalhousie Pluton. However, it should be stressed that similar map unit configurations could result from a component of dip-slip movement as suggested by Horne et al. (1992).

It is clear from the above section that faults and shear zones were important factors in the evolution of the batholith. Field observations reveal that the intensity of deformation along some faults is more intense in Stage I than Stage II plutons, suggesting these structures may have predated the emplacement of Stage II plutons. In fact, the dyke-like shape of the East Dalhousie pluton, (65 x 1.5 km), coupled with its intimate spatial association with the East Dalhousie-East



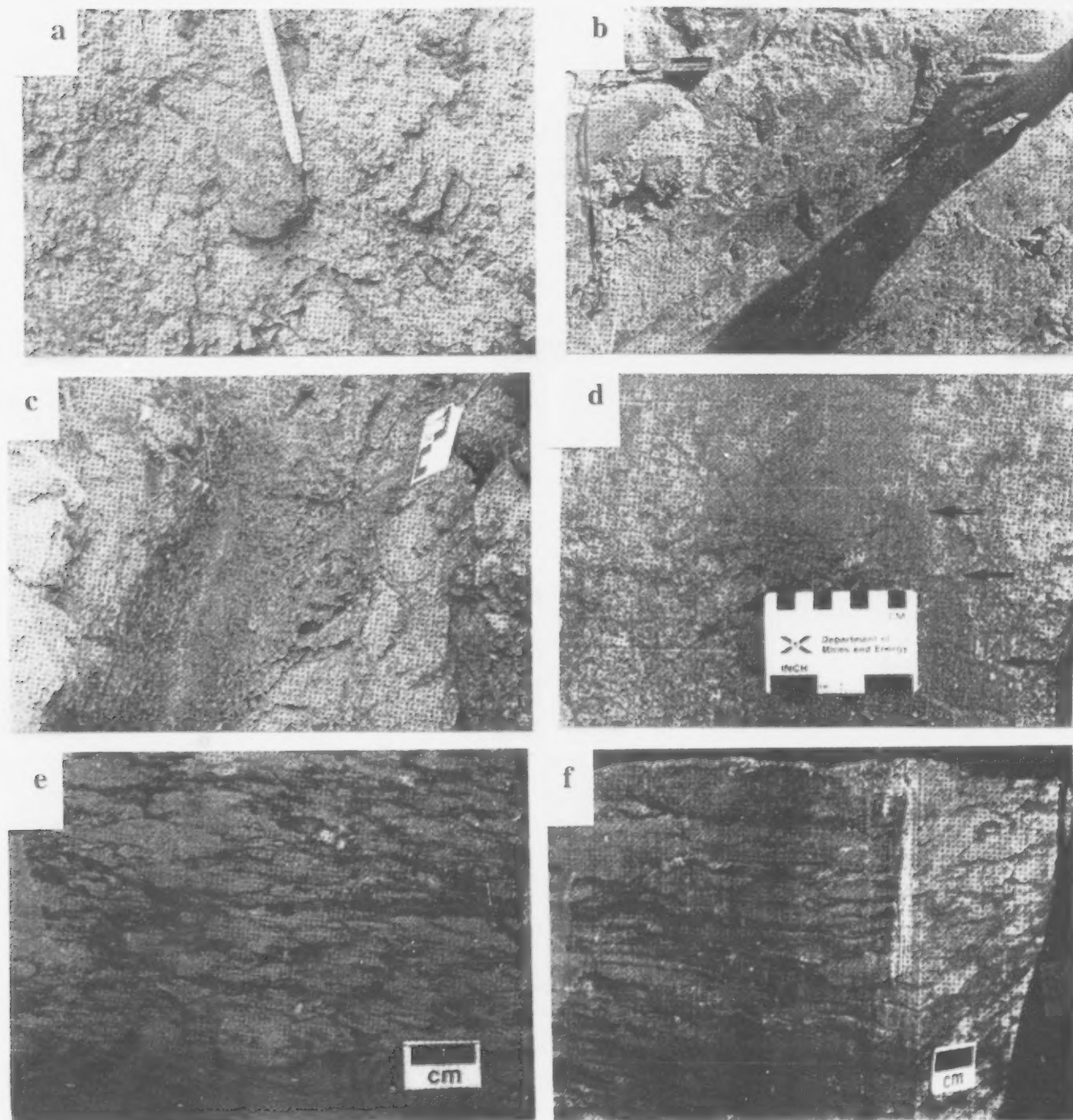


**Plate 6.7** Deformation associated with faults in the South Mountain Batholith: a) cataclasite zone in the Herring Cove brittle fault zone. Note the overall grain size reduction with rounded clasts of host rock in brecciated matrix; b) hematized slickenside fault surface in the East Dalhousie brittle fault zone; c) hematized fracture/shear zone from the Herring Cove brittle fault zone at Sheehan's Cove; d) intensely hematized, chloritized and silicified breccia from the East Dalhousie brittle fault zone. Note the offset by later fractures (arrows); e) C-S fabric from the Tobatic Lake ductile fault zone; f) rodded mylonite gneiss from Rocky Shore Lake in the East Kemptonville ductile shear zone.

Kemptville fault zone, suggests emplacement along a pre-existing structure. Several contacts between Stage I and II plutons are marked by major fault zones. Several NE- and NW-trending faults cross-cut, and notably deform, several map units in Stage II plutons, including the Murphy Lake and East Kemptville leucogranites (MacDonald and Ham, 1992; Kontak et al., 1986). Halter et al. (1993) suggested that the NE-trending East Kemptville fault "exercised an important control on the location and geometry of the deposit". Similarly, fine-grained leucomonzogranite bodies and the associated Mn-P-F mineralization at New Ross Manganese Mines are localized along NE-trending fault zones. The above field-based evidence indicates protracted deformation along many NE- and NW-trending faults, from the emplacement and crystallization of Stage I and II plutons to the formation of post-magmatic mineral deposits. Various geochronological studies (Kontak et al., 1990; and references therein) reveal episodic thermotectonism along the East Kemptville-East Dalhousie fault zone that continued after the crystallization of the Davis Lake Pluton to circa 250 Ma (see further discussion in Chapter 7).

#### 6.5 Mode of Emplacement of the South Mountain Batholith

Previous workers have concluded the batholith was emplaced by a passive stoping mechanism at the present level of erosion, primarily based on the ubiquitous distribution of metasedimentary xenoliths and the overall lack of deformation of the country rocks (Clarke and Muecke, 1985; Clarke and Chatterjee, 1988; and references therein). These observations and conclusions were largely supported by the results of recent mapping. For example, metasedimentary(?) xenoliths were observed in most megacrystic map units throughout the batholith with the relative proportions of xenoliths being proportional to the mafic mineral content of the rock as opposed to the proximity to country rock contacts (see discussion in Chapter 3). These observations support stoping throughout the entire batholith. Horne et al. (1992) concluded that the 'orthogonal' shape of the contacts in several locales supports emplacement of the batholith into pre-existing regional ('orthogonal') structures in the Meguma Group rocks.

Granite dykes are absent in many contact zones but were noted in a few locales, where dykes could be traced for up to 100m from the batholith contact (Plate 6.8b,c). The scarcity of dykes in country rocks is somewhat puzzling if stoping were the dominant emplacement mechanism.

There is evidence for deformation of country rocks in some areas of the batholith



suggesting localized forceful emplacement. These include:

- 1) A series of NW-trending structures termed the "transverse anticline" and "transverse

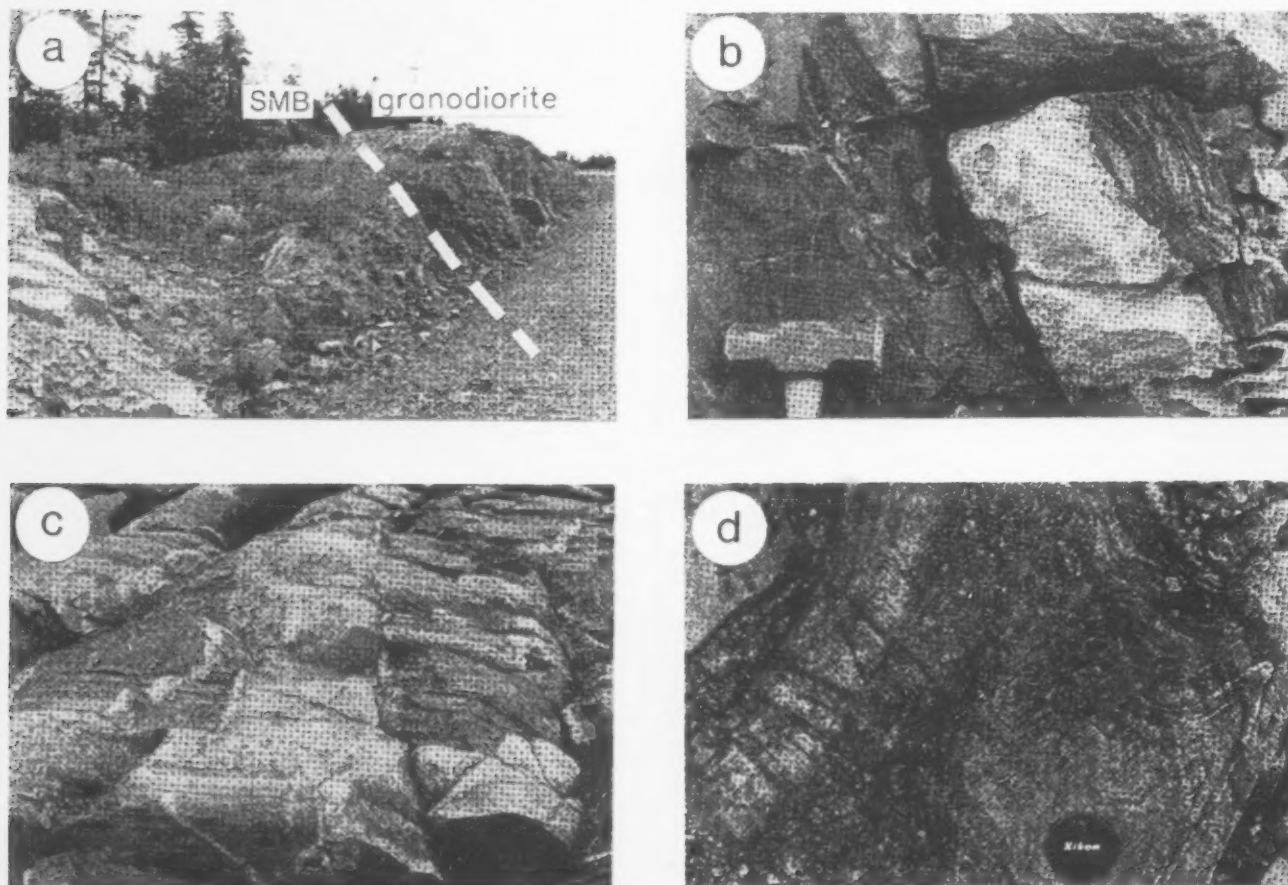


**Plate 6.8** Endobatholith features: a) sharp, steeply-dipping contact between biotite granodiorite and Meguma Group transition zone rocks along the Bicentennial Highway near Halifax. Note the lack of granite dykes; b) steeply-dipping aplite dyke intruding Meguma Group rocks along Bicentennial Highway. Note the dyke is sub-parallel to bedding; c) lit-par-lit injection of monzogranite dykes in a large metasedimentary xenolith at Portuguese Cove. Dykes follow bedding planes and cross-fractures; d) ptigmatic folds in the Meguma Group metasedimentary roof pendants in the Boot Lake area.

syncline" by Faribault (1908) are developed adjacent to the margin of the Halifax Pluton near Hammonds Plains (MacDonald and Horne, 1987). These structures are perpendicular to the regional NE structures and have been interpreted by MacDonald and Horne (1987) and Horne et al. (1992) to represent forceful emplacement of the batholith resulting in reorientation of structural trends;

- 2) O'Brien (1988) documented the occurrence of a steeply-plunging NW-trending large-

scale antiform, along Aspotogan Harbour near Mahone Bay, that parallels the batholith margin and refolds the Indian Path Anticline. The NE limb of this antiform is comprised of NW-trending granite screens and highly strained schist that markedly contrast the NE-trending screens and variably deformed hornfelses of the SW limb. Accordingly, this structure has been interpreted by O'Brien (1988) as originating from the forceful emplacement of the batholith.

3) Clarke and Halliday (1980) interpreted a weak foliation of cordierites in cleavage planes in the thermal aureole adjacent to the Halifax Pluton as representing late-syn to post-tectonic emplacement of the batholith with respect to cleavage formation. MacDonald (1981) reported similar porphyroblast foliation in a portion of the thermal aureole around the Musquodoboit Batholith and concluded that it resulted from compressive forces near the granite that were associated with buoyant forces of intrusion. Both explanations are considered to have merit.

4) Primary flow features vary from NE- to NNE- and N-trends in the SW part of the batholith and directly mirror the batholith margin and a regional warp in structural trends in adjoining country rocks (Fig 6.1). Horne et al. (1992) suggested that these features were formed by "ballooning" of the Scrag Lake and Davis Lake plutons. O'Reilly et al. (1992) presented a structural interpretation of the southern part of the Meguma Zone based upon airborne gradiometer data and geological mapping. Their data reveal that N- and intersecting NE-trending structures occur up to 100 km south of the batholith and, consequently, could not be formed by localized granite-related stresses. The southern part of the batholith is interpreted to have been emplaced into a structurally complex area where movement along faults and shears may have created "space" by local extension (Hutton, 1988), however, a component of forceful emplacement in this area cannot be ruled out.

The presence of **contact metamorphic minerals** was noted during mapping, however, the nature and extent of the aureole were not investigated in detail during the project. Taylor (1969) noted the contact aureole ranged from 0.8 to 2.5 km in width and consisted of porphyroblastic growth of cordierite and andalusite, particularly in pelitic beds, with partial to complete annealing of pre-existing cleavage in all rocks. Several workers including Taylor (1969) and O'Brien (1988) noted that porphyroblasts overgrew regional slaty cleavage with no preferred orientation. Mahoney (1996) examined the metamorphic aureole in 12 locations around the batholith and reported widths

ranging from 1.5-3km. Clearly, the presence of a well-defined aureole indicates the emplacement of a relatively 'hot' granite body, although does not preclude stoping as a mechanism.

As previously noted, many **contact zones** are characterized by steep granite contacts (Plates 3.2, 3.9, 6.8a). In contrast, the Boot Lake area of map 21A/15 (MacDonald and Ham, 1992) is dominated by complex outcrop patterns of monzogranite and metasedimentary rocks. Granite/metasediment contacts were not directly observed but this area was interpreted as a roof zone for the batholith by MacDonald and Ham (1992) and subsequently provides insight into the endocontact effects above the batholith. Lit-par-lit injection of biotite monzogranite, and lesser mafic porphyry, was noted in Meguma Group rocks in this area. In addition, locally-developed pygmy fold (Plate 6.8d) structures, that commonly have monzogranite or mafic porphyry injections with sinuous forms, were noted in restricted locales. Similar features were also documented in two roof pendants along the margin of the Kejimikujik Pluton (Horne, 1994) and are interpreted as resulting from intense heating and deformation from underlying granite magma(s). However, it should be stressed that these features are absent or rare in most areas with shallow-dipping contacts, as at the East Kemptville Sn Mine.

Contact-related features in the batholith, such as **chilled margins** and **primary flow features**, are generally absent. Notable exceptions include the chilled margin (generally 200-300m wide) along the northern margin of the Lake George leucomonzogranite (MacDonald and Ham, 1992), and the non-megacrystic or equigranular texture of biotite granodiorite units along the northern margin of the Halifax Pluton (MacDonald and Horne, 1987) and the Five Island Pluton (Corey, 1987) that may also represent large chilled margins.

#### 6.6 Sequence of Emplacement of Granite Units

In general, the lack of chilled margins and definitive cross-cutting relationships at most granite/granite contacts (e.g. Plates 3.5, 3.10) inhibit the determination of a comprehensive sequence of emplacement for the various plutons. However, some overall points can be made based on field observations. Granite/granite contacts are predominantly sharp and clearly, although some contact zones are gradational as noted between several megacrystic units in the Halifax Pluton. Gradational contacts have largely been interpreted to represent *in-situ* fractionation (MacDonald and Horne, 1987; MacDonald et al., 1992). It was previously noted in Chapter #3

that Stage II plutons intrude, and therefore post-date, Stage I plutons.

Fine-grained leucogranite and leucomonzogranite units were noted to intrude the coarse-grained megacrystic rocks with the exception of some porphyry bodies in the New Ross Pluton that were interpreted as chilled(?) phases of megacrystic leucomonzogranite rocks (e.g. Corey, 1990). Many of the fine-grained leucomonzogranite bodies within the Stage I and II plutons have linear contacts that are crudely oriented NE or NW (Fig. 2.3 in pocket at back). These orientations correspond to the major joint directions throughout the batholith which prompted Horne et al. (1988, 1992) and MacDonald et al. (1992) to propose that the emplacement of these bodies was also structurally controlled.

Stage I plutons mainly have elliptical shapes with long axes oriented to the NE, thus mirroring the regional structures in the country rocks and the primary flow features outlined in Figure 6.1. Horne et al. (1992) and MacDonald et al. (1992) concluded that these features were indicative of regional-scale NW-oriented compression during the waning stages of the Acadian Orogeny. Stage II plutons have circular or elliptical shapes with weakly developed circular primary flow features (Figure 6.1) and have been interpreted by MacDonald et al. (1992) and Horne et al. (1992) to have been emplaced into a lower stress regime than Stage I plutons.

McKenzie and Clarke (1975) postulated that the entire batholith crystallized from a single magma with a single crystallization sequence of granodiorite-monzogranite-leucomonzogranite. Field observations indicate a much more complex sequence of emplacement. Fine- to medium-grained leucomonzogranite xenoliths were noted in biotite monzogranite and biotite granodiorite in several Stage I plutons (Plate 3.16). The exact origin of these enclaves is unclear, however, it is likely that the biotite-rich granodiorite and monzogranite units intruded crystallized leucomonzogranite units, possibly from nearby or underlying Stage II(?) plutons.

The aforementioned observations indicate the granodiorite was crystallized, cooled, cracked, was intruded by aplite which in turn crystallized, followed by further fracturing and "falling" into the leucomonzogranite in the interior parts of the pluton. Similarly there are many occurrences of granite xenoliths that are both more primitive and more evolved than the host rocks. The implications of this are that the sequence of emplacement and crystallization that is generally accepted for the batholith may in fact be somewhat simplistic.

A series of outcrops, along the coastline to the south of Crystal Crescent Beach, in the Halifax Pluton, yield insight into the emplacement of granitic rocks. Several large blocks of biotite granodiorite (DCgd), measuring up to 5-7m in diameter, occur within coarse-grained Halifax Peninsula leucomonzogranite (Plate 6.9). Several of these granodiorite 'xenoliths' were bordered by, or contained, aplite dykes (<1-25 cm wide) and commonly contained metasedimentary xenoliths. Aplite dykes were frequently noted along two parallel sides of the granodiorite xenoliths but never on adjoining faces (Plate 6.9). No obvious chilled margins were noted in any of the granite phases. These features, coupled with the extremely angular shape of the granodiorite xenoliths indicate a sequence of emplacement that involves: 1) intrusion and crystallization of the granodiorite into the metasedimentary country rocks surrounding the Halifax Pluton. Metasedimentary xenoliths indicate the granodiorite was emplaced by stoping; 2) following crystallization, the granodiorite was then fractured (shrinkage feature?) and intruded by aplite dykes; 3) further fracturing in the granodiorite occurred preferentially along aplite dykes; 4) intrusion of coarse-grained Halifax Peninsula leucomonzogranite exploited the fractures and 'stoped' the more mafic (i.e. more dense) granodiorite blocks into their present configuration. The lack of chilled margins suggests that the granodiorite had not cooled significantly before the intrusion of the leucomonzogranite.

In short, field evidence supports the petrological and geochemical data previously presented in Chapters 4 and 5 and indicates that the overall sequence of emplacement of the various map bodies and units comprising the 13 plutons of the batholith was very complex. However, it should be stressed that the scarcity of exposed granite/granite contacts and the absence of definitive cross-cutting field relations at many contacts prohibits the establishment of a comprehensive sequence of emplacement for the batholith.

#### 6.7 Depth of Emplacement

The depth of emplacement can be estimated from a variety of field, textural and mineralogical evidence as outlined in the following sections.

##### 6.7.1 Field Constraints

The batholith intruded sedimentary rocks of the Torbrook Formation along its northern margin. Taylor (1969) concluded that this Formation ranges in thickness from 1.5 to 3.0 km which gives a crude approximation of minimum thickness. However, this estimate is subject to such parameters as tectonic thickening and/or denudation prior to granite emplacement.



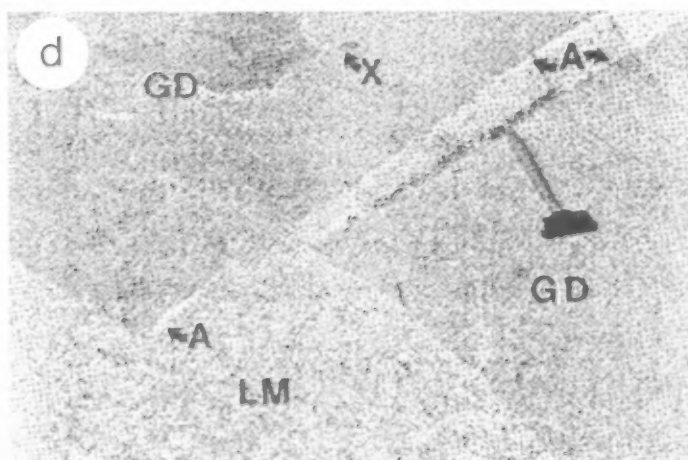
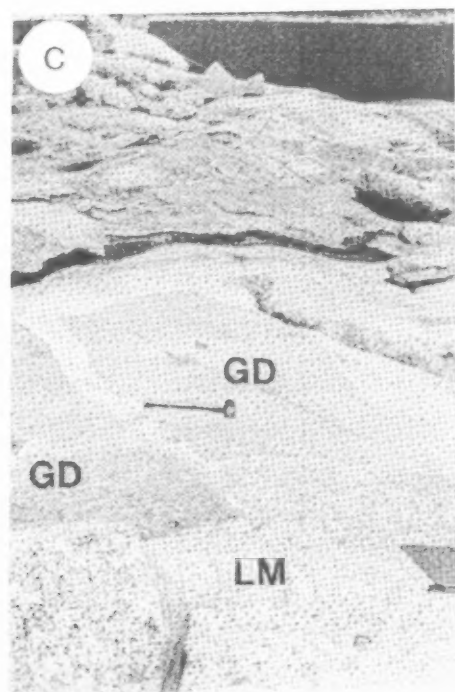
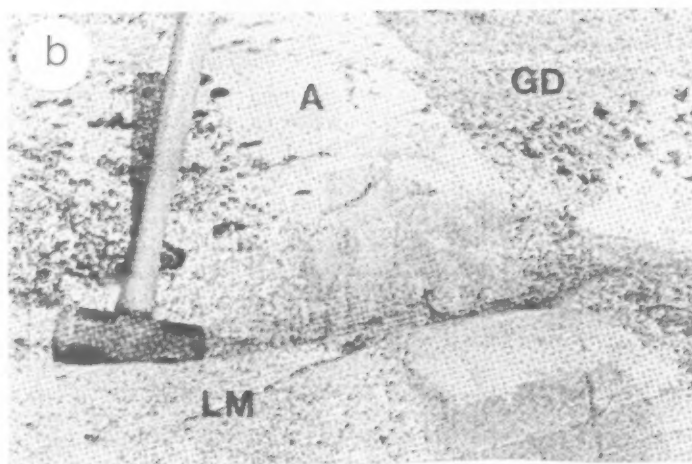
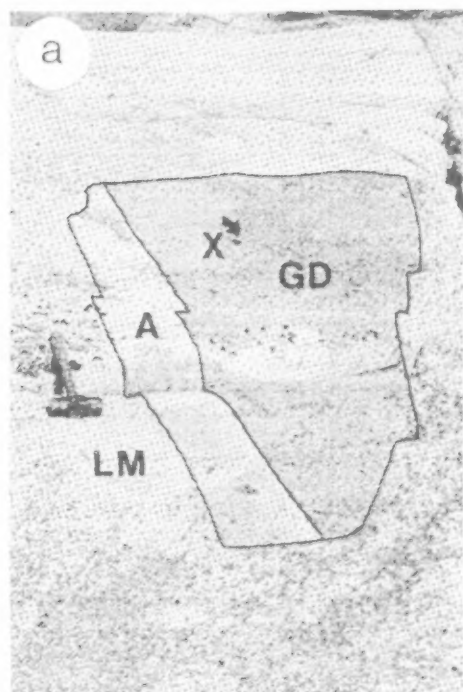


Plate 6.9 Granodiorite 'xenoliths' contained in coarse grained Halifax Peninsula leucomonzogranite near Crystal Crescent Beach along the southern margin of the Halifax Pluton. Granodiorite xenoliths commonly have Meguma Group(?) metasedimentary xenoliths and aplite dykes along one or more margins. GD = granodiorite; LM = leucomonzogranite; A = aplite; X = xenolith. Length of hammer is 40 cm.



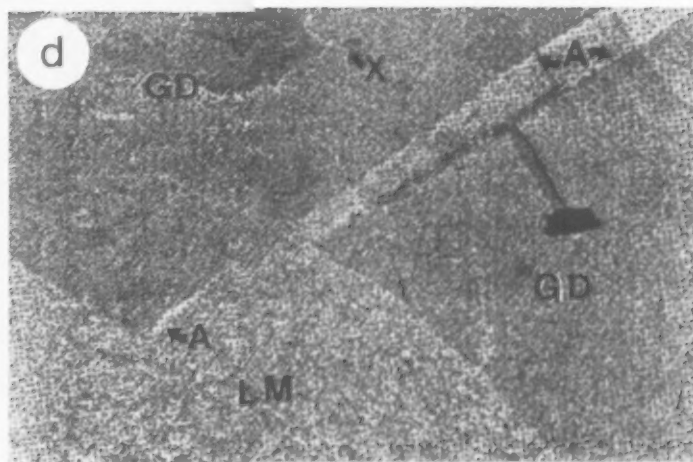
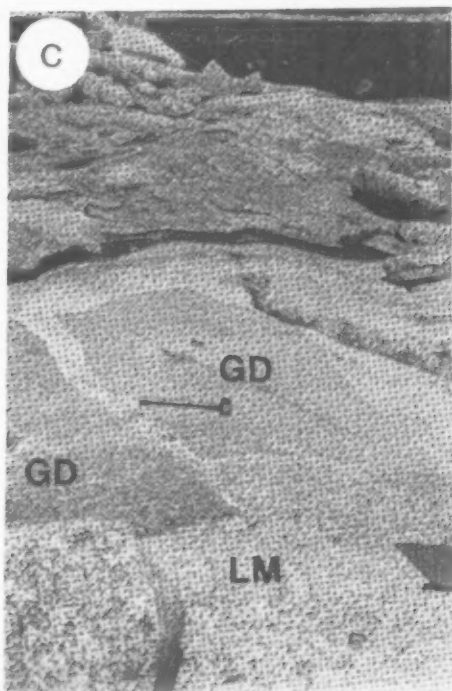
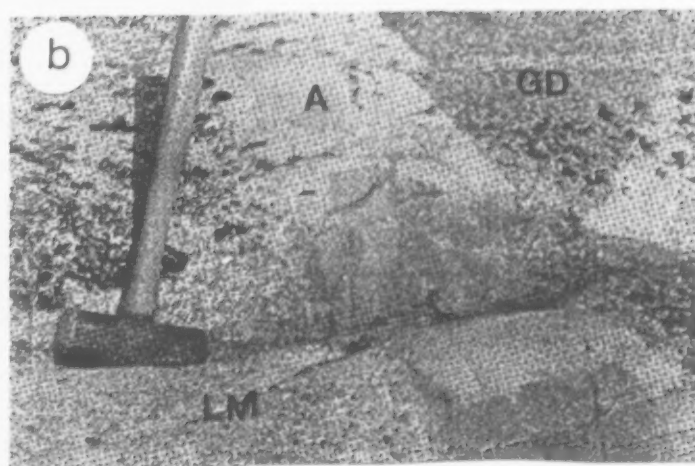
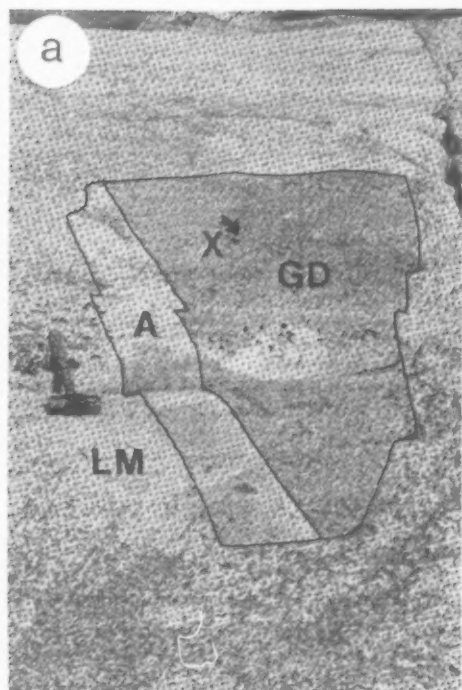


**Plate 6.9** Granodiorite 'xenoliths' contained in coarse grained Halifax Peninsula leucomonzogranite near Crystal Crescent Beach along the southern margin of the Halifax Pluton. Granodiorite xenoliths commonly have Meguma Group(?) metasedimentary xenoliths and aplite dykes along one or more margins. GD - granodiorite; LM - leucomonzogranite; A - aplite; X - xenolith. Length of hammer is 40 cm.

Estimates of depth of emplacement can be determined from the metamorphic grade of the country rocks surrounding the batholith. Most of the batholith is bordered by chlorite- or biotite-grade greenschist metamorphic rocks with the exception of the SW end where metamorphic grade increases to andalusite-staurolite-cordierite and sillimanite zones of the amphibolite facies (Keppie, 1979). Miyashiro (1973) concluded that P-T estimates using metamorphic isograds was difficult because of the multitude of factors that influence stability of the various mineral species. However, he noted that biotite (i.e. greenschist grade) was stable at T ranging from 350-400°C and P ranging from approximately 2-5 kb. In contrast amphibolite grade regional metamorphism is indicative of much higher P (up to 7kb) and T (up to 600-700°C). The exact origin of the amphibolite-grade metamorphism near the SW part of the batholith is not definitively known. That is, whether this zone represents increases in regional grade or the presence of a thermal dome.

Several features are consistent with shallow epizonal intrusion (i.e. < 10 km; Buddington, 1959). These include: sharp, largely discordant contacts with country rocks; presence of large stopped metasedimentary blocks; narrow contact metamorphic aureole that is commonly < 100 m wide; development of granophyric textures and rare miarolitic cavities (mainly in fine-grained leucomonzogranite and leucogranite).

#### 6.7.2 Mineralogical Constraints

McKenzie (1974) calculated normative An-Ab-Or for representative compositions from the batholith and compared these data to experimental studies. He concluded that the batholith must have crystallized between 1 and 4 kb, based upon these data.

Clarke et al. (1976) concluded that andalusite and muscovite crystallized as a primary magmatic phase in some late-stage rocks of the batholith. They concluded, on the basis of available experimental phase equilibria information, that the batholith crystallized at 3.3 to 3.9 kb and 650°C to 680°C. They employed the aluminosilicate phase diagram of Richardson (1969). Holdaway (1971) and Pattison (1992) have reported experimentally-derived aluminosilicate phase equilibria that differ significantly from the results of Richardson (1969). Their data do not allow for crystallization of andalusite in some granites. However, it should be noted that experimental studies indicate that the addition of both F and B to granitic melts has significant effect on both the granite solidus and the stability field for andalusite (Holdaway, 1971; Chorlton and Martin,

1978; Manning and Pichevant, 1983). In short, the estimation of depth of crystallization of the batholith based on the presence of 'magmatic' andalusite is currently considered problematic.

Ham and Kontak (1988) concluded, on the basis of textural and chemical data, that muscovite is present as a primary magmatic mineral in much of the batholith. They noted wide discrepancies in published P-T estimates for muscovite stability which were attained using independent field evidence and experimental data. Ham and Kontak (1988) concluded that muscovite crystallized at pressures approximating 2 kb from melts with 2-3 wt. %  $H_2O$  thus placing P constraints for the batholith.

Patino Douce et al. (1993) proposed a geothermometer/geobarometer that was based upon the fugacity of O in biotite. There is currently insufficient O fugacity data for biotite in the batholith to evaluate their proposed method but definitive depth calculations may be calculated if these data becomes available in future.

As previously noted, Mahoney (1996) conducted a study of the metamorphic aureole of the batholith. She calculated P-T conditions for the formation of the thermal metamorphism associated with the intrusion of the batholith using multicomponent equilibrium geothermobarometry for an equilibrium mineral assemblage. Mahoney (1996) reported pressures ranging from 250 MPa in the western part of the batholith to 400 MPa near the eastern margin of the batholith. These pressures correspond to depths of 6 km and 10 km depth for the western and eastern parts of the batholith respectively. This work represents the first definitive estimate of the depth of emplacement for granitic bodies in the Meguma Zone.

#### 6.8 Discussion and Summary

The South Mountain Batholith is, in general terms, massive and lacks the penetrative structural deformation that is characteristic of syn-tectonic or syn-kinematic granitoid bodies. Accordingly, it is interpreted to have been emplaced after the regional deformation associated with the Middle Devonian Acadian Orogeny. However, it is evident from the observations in the previous sections that the batholith was subject to regional stresses during, and subsequent to, emplacement and crystallization.

The NE-trending elongate shape of, and the predominance of NE-trending primary flow features in, several Stage I plutons may reflect structural control during initial stages of batholith emplacement. Conversely, their shape may reflect the exploitation of pre-existing structures in

the country rocks by the intruding Stage I plutons as noted for other granite batholiths around the world (Castro, 1986 and references therein).

Some faults in Stage I plutons show evidence that they were active following crystallization of Stage I plutons and prior to the emplacement of Stage II plutons.

Granite/metasediment contacts are sharp and intrusive, for the most part, and show virtually no signs of deformation of the country rocks. The two notable exceptions include the "Transverse anticline" and the Aspotogan Harbour area where the batholith has been interpreted to have been forcefully emplaced. It is unclear whether the coincidence of north-trending regional structural and primary flow features in the batholith in the western end of the batholith represent "ballooning" or lateral forces associated with emplacement of the batholith or were generated by regional structural forces.

The East Dalhousie pluton and the southwestern extension of the Davis Lake pluton have narrow, NE-trending, dyke-like shapes and are flanked by a series of faults and/or shear zones (Fig. 6.5). In several locales these Stage II plutons have been variably deformed by movement/strain along these faults. These observations prompted Horne et al. (1988; 1992) to suggest that the entire batholith was localized along a crustal-scale structure. Results of a recent geochronological study of the East Kemptville-East Dalhousie Fault Zone, which partially forms the northern boundary of both plutons, indicates that these faults were episodically active from ca. 350 to 250 Ma (Kontak et al., 1989; Kontak and Cormier, 1991). One explanation for the coincidence of faults and pluton boundaries is that some Stage II plutons were emplaced along pre-existing structures that remained active for ca. 120 Ma subsequent to their emplacement (Horne et al., 1992). Conversely, the Stage II plutons may have intruded and crystallized and subsequently emplaced to their present configuration by displacement along the observed faults. More structural data pertaining to the movement along the sundry faults of the batholith must first be collected before this issue can be resolved.

The predominantly circular shape of Stage II plutons and the concentric primary flow trends in the Halifax and New Ross plutons, which sharply contrast the Stage I plutons, may indicate that the compressive forces on the batholith may have diminished somewhat between the emplacement of Stage I and II plutons. However, the orthogonal or dyke-like shape of some fine-grained leucomonzogranite bodies in Stage II plutons has been interpreted as reflecting intrusion

along pre-existing structures in the coarse-grained megacrystic host rocks (Horne et al., 1992). These structures were presumably formed by regional compression on the batholith.

The structural data for joints, dykes, veins faults and shear zones, outlined above, demonstrate that the batholith was emplaced and crystallized in a weak regional stress regime. Horne et al. (1988, 1992) concluded that these planar features developed during northwest, horizontal compression accompanying uplift during the waning stages of the Acadian Orogenic event. The occurrence of NW-trending ( $315^{\circ}$ ,  $325^{\circ}$ ,  $335^{\circ}$ ) joints interpreted as tension joints and recurrently occupied by quartz veins or dykes, and NE-trending ( $040^{\circ}$ ,  $062^{\circ}$ ) shear/fracture zones which are interpreted as P and R (Riedel shear geometry) are consistent with NW-directed transpression and presumably dextral displacement along NE-trending faults.

The exact origin of some of the above structural features is somewhat contentious and requires additional study, however, it is evident from the above features that the batholith was subjected to regional stresses commencing with the earliest emplacement of Stage I plutons to the terminal stages during which time mineralization occurred. These regional stresses probably relate to the waning stages of the Acadian Orogeny and also are manifest as transpressional displacement along the Cobequid-Chedabucto Fault Zone (Fig. 1.2).



*Chapter 7*

## GEOCHRONOLOGY

## 7.1 Field and Paleontological Evidence

Stage I and II plutons of the South Mountain Batholith intrude the conformable sequence of Cambro-Ordovician Meguma Group metasedimentary rocks and overlying Ordovician to Lower Devonian White Rock, Kentville, New Canaan and Torbrook formations (Taylor, 1969; Smitheringale, 1973). It should be noted that youngest Torbrook Formation is intruded by the Scrag Lake and Cloud Lake Stage I plutons which are interpreted as being among the first plutons to be emplaced. Since Boucot (1960) identified Lower Emsian fauna in the marine Torbrook Formation and the Early Devonian (Emsian) - Middle Devonian boundary has recently been defined at ca. 385 Ma by Cowie and Bassett (1989), this indicates the batholith has a maximum post Emsian age.

Despite the late, or residual, Acadian structural influence, outlined in Chapter 6, the batholith cross-cuts regional structural trends and has been interpreted as post-dating regional metamorphism and deformation of the Cambrian to Devonian country rocks (McKenzie and Clarke, 1975; MacDonald et al., 1992, and references therein). Reynolds et al. (1973) calculated K-Ar "metamorphic" ages for 15 whole-rock slates (biotite- and chlorite-zone of greenschist facies) from the Meguma Group rocks. They reported apparent ages of 332-405 Ma but concluded that the minimum age for the regional metamorphism was ca 390 Ma. Reynolds and Muecke (1978) concluded the regional metamorphism and deformation of the Meguma Group rocks occurred at least 400-415 Ma, based upon  $^{40}\text{Ar}/^{39}\text{Ar}$  ages for greenschist facies slates. They also noted that the  $^{40}\text{Ar}/^{39}\text{Ar}$  age spectra from several hornfels and slate samples were completely reset by thermal effects from the South Mountain Batholith. Muecke et al. (1988) reported  $^{40}\text{Ar}/^{39}\text{Ar}$  age determinations for micas, hornblendes and six whole-rock slate and siltstone samples from metamorphic rocks of the Meguma Zone. They noted a convergence of whole-rock and hornblende and biotite ages at circa 405-390 Ma and interpreted this intersection to represent the timing of the regional metamorphism. Similarly, Dallmeyer and Keppie (1987) reported "younger" ages ranging from  $366.9 \pm 5.6$  Ma and  $385.1 \pm 2.6$  Ma for amphiboles from calc-silicate horizons from granite contact aureoles. Keppie and Dallmeyer (1987) reported  $^{40}\text{Ar}/^{39}\text{Ar}$  age plateaus ranging from 375-400 for whole-rock slate samples from high temperature



contact aureoles in the eastern Meguma Terrane. These "younger" ages were concluded to reflect partial resetting from granite emplacement rather than regional metamorphism.

Several Stage I plutons (e.g. Salmontail Lake) and the Stage II Halifax Pluton are overlain by the coarse, subaerial clastic sediments and marine carbonates of the Horton and Windsor groups. Bell and Blenkinsop (1960) and Howie and Barss (1975) concluded that the Horton Group was deposited during the Early Carboniferous (Tournaisian). Utting et al. (1989) also proposed an Early Carboniferous (Tournaisian) age for this formation based upon their identification of miospore assemblages. Martel et al. (1993) have recently identified Early Tournaisian (Courceyan) and Upper Devonian (Late Famennian) miospores in the lowermost 7.3 m of Horton Bluff sediments in the type area. The Devonian - Carboniferous boundary has recently been placed at 355 Ma by Cowie and Bassett (1989) which firmly constrains the age of deposition for the basal strata of the Horton Group.

Field and paleontological evidence indicates that the batholith must have been emplaced, crystallized, uplifted and unroofed during a narrow time interval. Paleontological evidence suggests this event occurred between the post-Emsian (i.e. Early Devonian; ca. 385 Ma) and late Famennian (i.e. Late Devonian; ca. 355 Ma) ages. Geochronological studies of regional metamorphism and deformation have yielded conflicting dates which reflect both regional metamorphism/deformation and subsequent resetting of ages either from thermal effect associated with granite intrusion or from thermotectonic deformation of the Meguma Terrane. However, the tightly-constrained paleontological data restricts regional deformation/metamorphism to post 385 Ma.

## 7.2 Summary of Geochronological Studies

There have been numerous radiogenic isotope studies (Rb-Sr, K-Ar,  $^{40}\text{Ar}/^{39}\text{Ar}$ , U-Pb, Pb-Pb) of the batholith during the past three decades. The salient aspects of these investigations are summarized in the following section.

The first systematic geochronological studies of the batholith and other Meguma Zone granites were done by Fairbairn et al. (1960, 1964), Lowden (1960, 1961), Lowden et al. (1963), Leech et al. (1963) and Reynolds et al. (1973). These authors employed Rb-Sr or K-Ar methods for whole-rock and/or mineral separates from samples collected throughout the batholith but, in general, did not attempt to differentiate among its various granitic phases. Reynolds

et al. (1981) noted that these studies yielded apparent ages ranging from circa 240 to 420 Ma. Cormier and Smith (1973) analysed granitic rocks from the eastern half of the batholith including the Halifax Pluton using the whole-rock Rb-Sr dating method. They concluded that two separate rock sequences with differing ages were present. These include: 1)  $417 \pm 38$  and  $387 \pm 25$  Ma for rocks corresponding to granodiorite-biotite monzogranite-muscovite-biotite monzogranite-coarse-grained leucomonzogranite of this study; and 2)  $357 \pm 10$  and  $350 \pm 7$  Ma for late-staged "alaskites" (i.e. fine-grained leucomonzogranite of this study) from the Halifax-St. Margaret's Bay and New Ross areas respectively. The ages reported by Cormier and Smith (1973) have recently been recalculated using revised half-life values ( $1.42 \times 10^{11}$  vs.  $1.39 \times 10^{11}$ ; R.F. Cormier, personal communication, 1994)) resulting in "younger" ages (e.g. ca. 395 compared with 417 Ma), however, the circa 60 Ma. difference in ages between the two granite suites persisted.

The wide range of ages from the above studies are contradictory to the field evidence outlined above. In particular, ages exceeding 400 Ma. would imply that the granitic rocks were intruded and crystallized through Rb-Sr and K-Ar "blocking temperatures" prior to deposition of the intruded country rocks. Similarly, young ages (i.e. 240-300 Ma) would dictate that some granitic rocks were intruded after the deposition of Carboniferous sediments that onlap over parts of the batholith.

Reynolds et al., (1980, 1981) determined the ages of granitoid rocks from the Meguma Zone using K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  methods on biotite, muscovite and feldspar separates. With the exception of one discordant age spectrum, samples from the batholith ranged from 351 to 380 Ma with a mean age of  $366.7 \pm 1.3$  Ma ( $N=23$ ). Reynolds et al. (1981) concluded that the age of the biotite granodiorite (366.6 Ma) was indistinguishable from the age of the "younger" adamellites and late intrusions (366.8 Ma). They concluded that temperatures throughout the batholith must have remained above the "argon retention temperatures" (ca. 300-350°C for biotite; ca. 350°C for muscovite; McDougall and Harrison, 1988) until the intrusion of the late intrusive bodies. Clarke and Halliday (1980) calculated Rb-Sr isochrons for whole-rock samples and mineral separates (plagioclase, alkali feldspar, biotite and muscovite). Their samples were collected during the mapping of McKenzie (1974) and Charest (1976) and included 'granodiorite, adamellite and porphyry' which correspond to: granodiorite and biotite monzogranite:

muscovite-biotite monzogranite and coarse-grained leucomonzogranite; and fine-grained leucomonzogranite and leucogranite of this study. They noted systematic variations in both age and initial ratios for the three rock phases including: granodiorite -  $371.8 \pm 2.2$  Ma, ( $\text{Sr}^{87}/\text{Sr}^{86}$ ),  $0.7076 \pm 0.0003$  to  $0.7090 \pm 0.0003$ , avg. 0.7081; adamellite -  $364.3 \pm 1.3$  Ma, ( $\text{Sr}^{87}/\text{Sr}^{86}$ ),  $0.70942 \pm 35$ ; and porphyry -  $361.2 \pm 1.4$  Ma, ( $\text{Sr}^{87}/\text{Sr}^{86}$ ),  $0.71021 \pm 119$ . They concluded that the age difference between the granodiorite and late-stage porphyries confirmed the intrusive sequence and represented emplacement of early granodiorite, adamellites and late-staged intrusive bodies over a 10 My time interval.

Harper (1988) determined ages for part of the same suite of samples used in the study of Clarke and Halliday (1980) using both Rb-Sr and U/Pb techniques. He reproduced the same apparent age of the monzogranite (i.e. adamellite) but suggested a primary crystallization age of  $371 \pm 5$  Ma for muscovite separates. He also was able to reproduce their  $361 \pm 2$  Ma age for leucomonzogranite (i.e. porphyry) but, once again, indicated a primary crystallization age of  $369.6 \pm 6$  Ma for muscovite separates. Harper determined U-Pb ages of  $374.3 \pm 1.9$  and  $372.8 \pm 2.1$  Ma for monazite separates from monzogranite and leucomonzogranite respectively. Harper's (1988) work established that all phases of the batholith crystallized circa 370 Ma and, consequently, the circa 10 My gap in Rb-Sr isochron ages may reflect disruptions in this isotopic system.

O'Reilly et al. (1985) calculated Rb-Sr whole-rock and muscovite ages for leucomonzogranite and leucogranite rocks associated with polymetallic deposits in the eastern part of the batholith. They reported "young" whole-rock ages of  $332 \pm 10$  Ma (MSWD = 1.53, N=6) and  $270 \pm 14$  Ma (MSWD = 1.21, N=5) for the Long Lake and Westfield deposits respectively and  $281 \pm 5$  Ma for the Lake Darling deposit. They suggested that these ages, which strongly contrasted the older (ca. 370 Ma) ages for much of the batholith, constituted evidence for Carboniferous-aged magmatism and mineralization.

Zentilli and Reynolds (1985) reported  $^{40}\text{Ar}/^{39}\text{Ar}$  ages for muscovite and biotite separates from the East Kemptville Sn deposit and its host Davis Lake Pluton. They noted that ages in, and immediately adjacent to, the deposit ranged from 295-350 which contrasted with ages ranging from 317-372 in other portions of the Davis Lake Pluton. They concluded that the circa 300 Ma plateau ages for muscovite greisen from the East Kemptville deposit represented the age

of mineralization and attending hydrothermal alteration.

Reynolds et al. (1987) measured  $^{40}\text{Ar}/^{39}\text{Ar}$  ages for micas, K-feldspars and hornblendes from several plutons in the southern part of the Meguma Zone. They concluded that most of the plutons were intruded at 370 Ma, along with the batholith. In addition they reported several "younger" ages that were interpreted as representing a later thermal event at circa 300-320. They also reported an episode of argon loss between 220 and 230 Ma in K-feldspars from the southern plutons that was also interpreted as a "thermal pulse".

Richardson et al. (1989) presented Rb-Sr geochronological and geochemical evidence to suggest that the Davis Lake Pluton was of Carboniferous age and unrelated to the remainder of the Devonian-aged South Mountain Batholith. They reported a whole-rock Rb-Sr "scatterchron" age of  $336 \pm 14$  Ma (MSWD = 24) for eight samples of biotite monzogranite and biotite-chlorite-muscovite monzogranite (i.e. Davis Lake Leucomonzogranite of this study). They also calculated a Rb-Sr isochron for five samples, collected away from the granite/metasediment contact, which yielded a  $330 \pm 7$  Ma age (MSWD = 2.8). They concluded that Sr from assimilated metasedimentary rocks was responsible for the three samples near the contact having isotopic heterogeneities resulting in large MSWD values. Richardson et al. (1989) interpreted the five point Rb/Sr isochron age of  $330 \pm 7$  Ma to represent the time of intrusion and crystallization of the Davis Lake pluton, despite the previously published  $^{40}\text{Ar}/^{39}\text{Ar}$  mica dates of ca. 370 Ma (Reynolds et al., 1981; Zentilli and Reynolds, 1985). The data of Richardson et al. (1989) have recently been recalculated and subsequently yield an isochron age of circa 370 Ma (D.J. Kontak, personal communication, 1994). The discrepancy between these ages is tentatively interpreted as stemming from mathematical errors in the calculations of Richardson et al. (1989).

Kontak et al. (1989) and Kontak and Cormier (1991) determined Rb-Sr isochrons for whole-rock and mineral separate (muscovite, plagioclase, K-feldspar) and  $^{40}\text{Ar}/^{39}\text{Ar}$  age determinations on muscovite separates for 11 samples of the East Kemptville leucogranite. They reported an 11 point Rb-Sr isochron of  $344 \pm 5$  Ma that was consistent with some age spectra of  $338 \pm 2$  Ma for muscovite separates. Kontak and Cormier (1991) concluded that internal re-equilibration of Sr among mineral separates and whole-rock had occurred. They reported Rb-Sr isochron ages of 361-311 Ma (average age 330 Ma) for seven whole-rock - muscovite pairs and 276-240 Ma (average age 254 Ma) for seven whole-rock - plagioclase - K-feldspar groups. An

Rb-Sr isochron age of  $320 \pm 4$  Ma was determined for seven muscovite separates. They also noted wide ranges in  $^{40}\text{Ar}/^{39}\text{Ar}$  age spectra with strong discordance of age spectra, particularly in low temperature "steps". Kontak and Cormier (1991) explained the wide ranges of ages, re-equilibration for Sr and discordant  $^{40}\text{Ar}/^{39}\text{Ar}$  spectra as representing episodic thermotectonism along the East Kemptville shear zone.

Clarke et al. (1993) determined  $^{40}\text{Ar}/^{39}\text{Ar}$  age spectra for high purity ( $>99\%$ ) muscovite separates from 12 leucogranite and leucomonzogranite bodies from the eastern portion of the batholith (Figure 7.1). They concluded that the step-wise release spectra yielded excellent

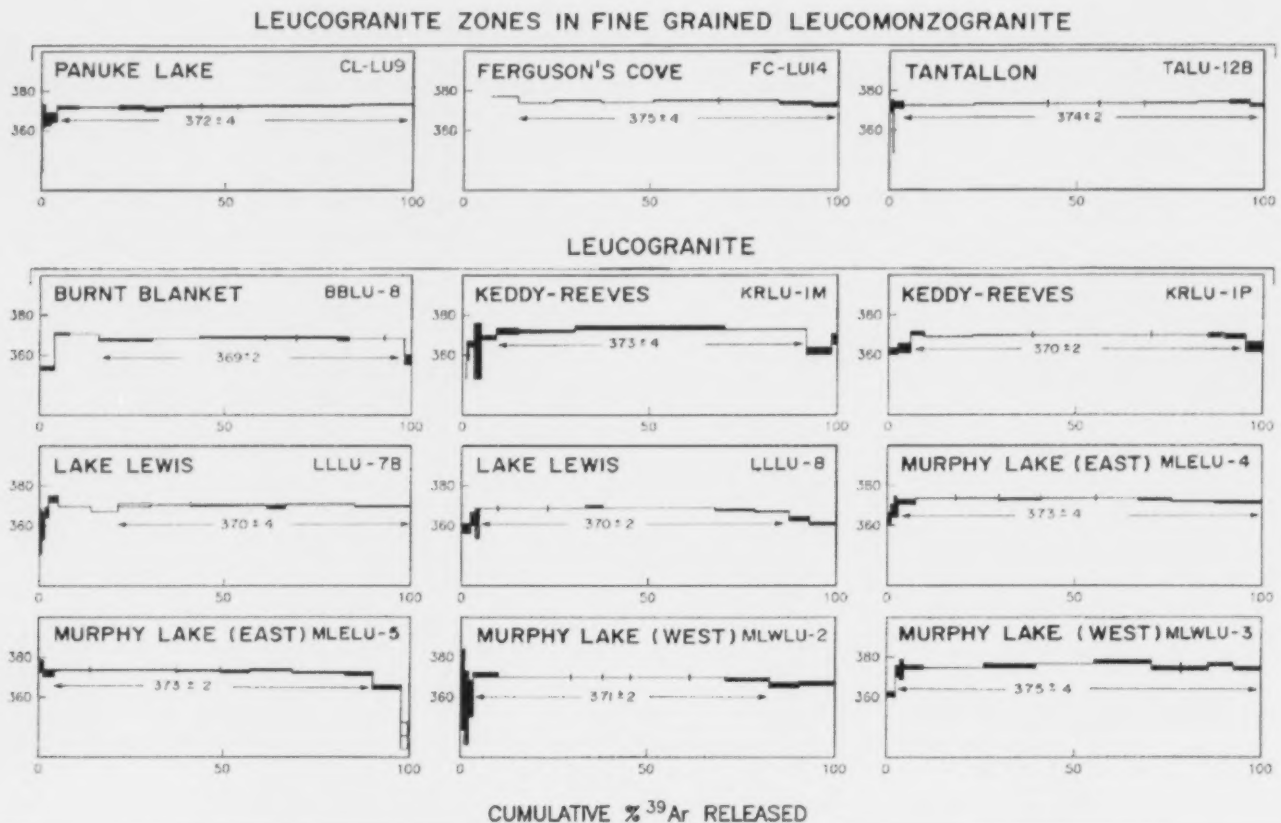


**Figure 7.1**  $^{40}\text{Ar}/^{39}\text{Ar}$  age spectra for twelve muscovite separates from leucogranite samples from the eastern portion of the South Mountain Batholith (modified after Clarke et al., 1993). The three spectra at top are from leucogranite zones within fine grained leucomonzogranite bodies whereas the nine spectra at the bottom are from discrete leucogranite bodies.

plateaus for all samples. They noted slight lowering of the apparent age of some samples over the first few percent of gas released. The plateau ages from their study ranged from  $369 \pm 2$  Ma to  $375 \pm 4$  Ma with a mean plateau age of  $371.5 \pm 2.5$  Ma for the entire data set. Their data



confirms that the ages of the late-stage leucogranites are remarkably similar to early granodiorite units. Clarke et al. (1993) noted that the consistency of published ages derived using the K-Ar,  $^{40}\text{Ar}/^{39}\text{Ar}$ , Rb-Sr, U-Pb and Pb-Pb isotopic systems necessitates rapid crystallization and cooling of the batholith.

Keppie et al. (1993) determined ages for sample suites from the Millet Brook (U-Cu-Ag) and Westfield (W-Sn-Cu-Pb-Zn-Au-Ag) deposits. They used  $^{40}\text{Ar}/^{39}\text{Ar}$  techniques for muscovite separates and U-Pb methods for monazite and zircon separates. The granodiorite from the Millet Brook area yielded a  $377 \pm 5/-3$  Ma age (concordant U-Pb monazite date). They also calculated ages of 377-373 Ma, based on  $^{40}\text{Ar}/^{39}\text{Ar}$  plateau ages for muscovite, for the late leucomonzogranite intrusions in drill core from the Millet Brook deposit and nearby New Ross Pluton. They noted that these dates were significantly older than the Rb-Sr dates reported by Clarke and Halliday (1980). A U-Pb age of  $385 \pm 2$  Ma was obtained for a zircon sample (intercept age) from the fine-grained leucomonzogranite porphyry at Westfield. This age was in sharp contrast to previously Rb-Sr age of  $270 \pm 15$  Ma (O'Reilly et al., 1985). Keppie et al. (1993) concluded that the age discrepancies between their study and previous works represented fluid-related isotopic resetting of Rb-Sr whole-rock and mineral systems. Conversely, their U-Pb dates could also be explained by a component of inheritance.

Chatterjee and Ham (1991) reported U, Th, Pb and Pb isotopic compositions for 34 samples from stage I and II plutons from throughout the batholith. They calculated whole-rock - mineral separate Pb-Pb isochron ages for biotite granodiorite from a Stage I pluton ( $373.3 \pm 3.6$  Ma; MSWD = 2.85) and leucogranite from a Stage II pluton ( $365.2 \pm 5.4$  Ma; MSWD = 2.57). Chatterjee and MacDonald (1991) reported a Pb-Pb isochron age of  $365.7 \pm 2.7$  Ma; MSWD = 1.95) for two chemically distinct suites of mineralized greisens from the East Kemptville Sn deposit and elsewhere in the Davis Lake Pluton. They also reported a Pb-Pb isochron age of  $366.0 \pm 5.6$  Ma (MSWD = 1.79) for these same greisens and their host leucogranite bodies which approximates a Pb-Pb age of  $367.4 \pm 4.70$  Ma (MSWD = 3.18) for a suite of 24 samples of greisen, leucogranite and coarse-grained leucomonzogranite from the southwestern portion of the Davis Lake Pluton (Figure 7.2a,b; unpublished data, A.K. Chatterjee, 1994). The above results indicate mineralization and crystallization of leucogranite at the East Kemptville deposit were coeval with crystallization of the rest of the Davis Lake Pluton and indeed the entire batholith (cf. Richardson et al., 1989).



Kontak and Chatterjee (1992) conducted a Pb isotopic study of twelve leucogranite samples representing the entire compositional range of the East Kemptville leucogranite and for four galena separates from mineralized greisens at the East Kemptville deposit. They interpreted the close spatial association of galena and black, cassiterite-bearing greisen to represent overlapping paragenesis. In addition to whole-rock analysis, these authors carried out sequential leachate determinations on a mineralized topaz greisen (23% Sn) and on K-feldspar and muscovite separates from one leucogranite sample. The entire Pb-Pb data set, including barren and mineralized leucogranite and greisen, indicated an age of  $366 \pm 4$  Ma (MSWD = 2.63), thus confirming the coeval nature of crystallization of leucogranite and mineralization in the East Kemptville deposit.

### 7.3 Summary and Discussion

Paleontological data from country rocks and unconformably overlying strata, coupled with geochronological data for deformation and metamorphism in country rocks, constrains the age of intrusion of the batholith to between circa 385 and 355 Ma. The geochronological studies of the granitic rocks of the batholith, outlined above, indicate that all Stage I and II plutons were emplaced, crystallized and generated mineralization within a very narrow time interval, say  $\leq 5$  Ma at ca. 370 Ma. The concordancy of all the radiometric dating techniques (i.e. K-Ar,  $^{40}\text{Ar}/^{39}\text{Ar}$ , Rb-Sr, U-Pb and Pb-Pb) which collectively have a large range in terms of blocking temperatures (i.e. near the solidus to ca. 250°C) implies rapid post-crystallization cooling. Therefore, exhumation must have initiated soon after, or indeed synchronously with, crystallization of the batholith.

Results from Rb-Sr geochronological studies have yielded ages ranging from circa 240-380 Ma although many of the dates cluster around 370 Ma. Some of the variation in the results from early studies (e.g. Fairbairn et al., 1960, 1964) may have arisen from poor analytical apparatus, poor quality standards (i.e. "spikes") or from the use of different half-life constants. However, the diversity of ages from more recent studies have been interpreted as reflecting geological processes in the batholith. A plot of age-corrected (372 Ma) initial ratios for 110 published Rb-Sr isotopic analyses, along with sample locations, is given in Figure 7.3a (unpublished information, A.K. Chatterjee, 1993). Initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios range from 0.680 to 0.724 for the entire data set, which has a K/Rb range of 33-250. Two sub-sets of data were selected for study including

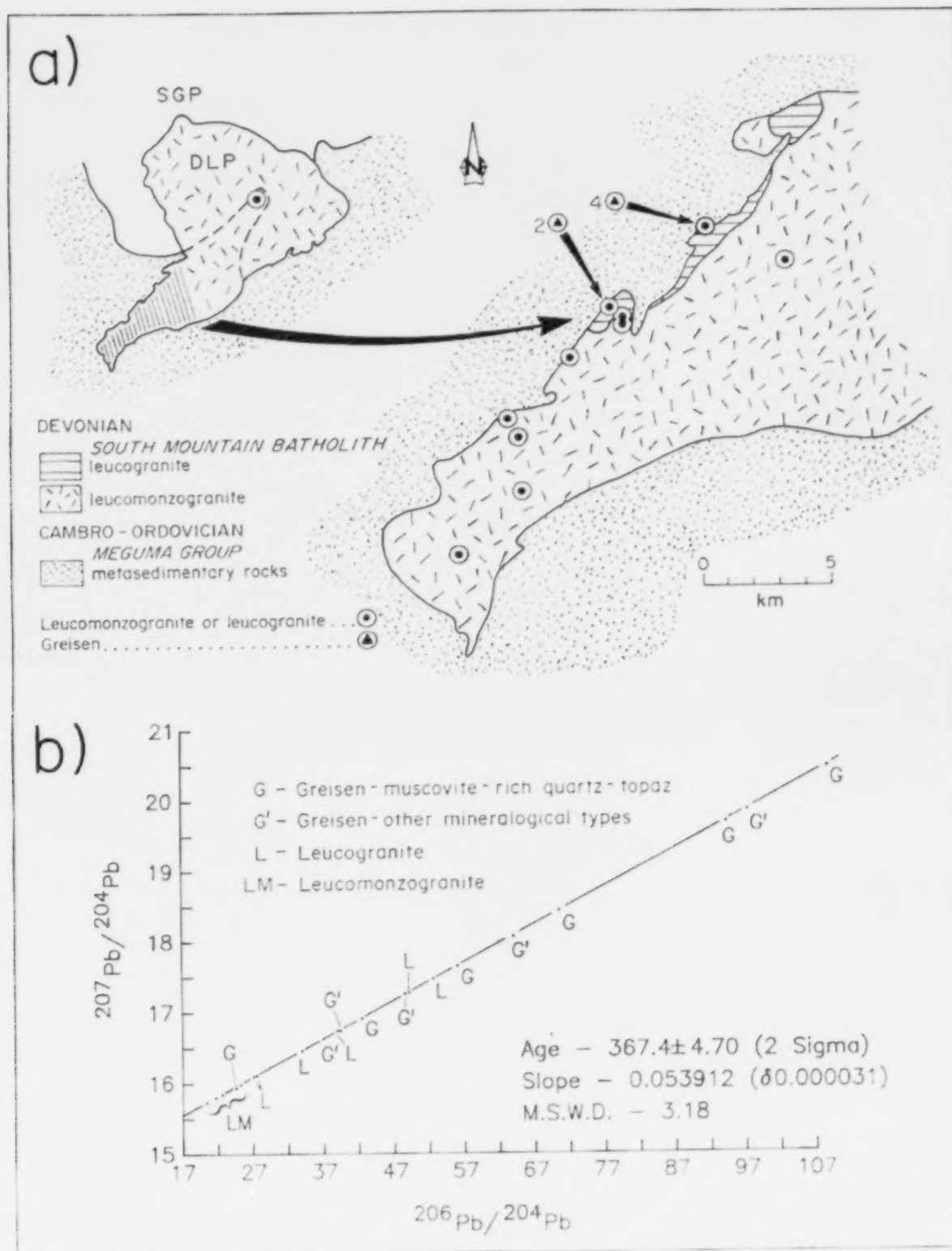


Figure 7.2 Pb-Pb isotopic analyses for a suite of 24 samples of greisen, leucogranite and coarse-grained leucomonzogranite from the southwestern portion of the Davis Lake Pluton (unpublished data, A.K. Chatterjee, 1994). a) sample location map; b)  $^{207}\text{Pb}/^{204}\text{Pb}$  versus  $^{206}\text{Pb}/^{204}\text{Pb}$  plot for the entire data set ( $N=24$ ).

samples with K/Rb values of 100-250 and 150-250 and are plotted in Figures 7.3b and c. Clearly, as samples with increasing K/Rb are selected, the initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios become more tightly constrained (0.704-0.710 for K/Rb = 100-250; 0.706-0.708 for K/Rb = 150-250). In Chapter 5 it was demonstrated that K/Rb is an effective measure of the degree of fluid/rock or fluid/melt interaction and that rocks with K/Rb  $\geq$  150 have largely been unaffected by fluids. Therefore the data presented in Figure 7.3 suggests that the Sr isotopic system has been disrupted by fluid-related interaction. Clearly this disturbance may be localized along structural features where episodic thermotectonism has been documented, such as along the East Kemptville Shear Zone (Kontak and Cormier, 1991). However, it should be noted that this isotopic disruption may also explain younger Rb-Sr ages, such as those reported by Clarke and Halliday (1980), in regions of the batholith with no pronounced structural deformation.

The majority of ages for the granitic rocks of the batholith, derived using K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  methods, cluster around circa 370 Ma (e.g Reynolds et al., 1980, 1981; Clarke et al., 1993). However, like the data for the Rb/Sr isotopic system, there is a wide spectrum of reported K-Rb and  $^{40}\text{Ar}/^{39}\text{Ar}$  ages for the batholith ranging from circa 250-370 Ma. Some workers have ascribed these 'young' ages to resetting from 'thermal pulse(s)' (Reynolds et al., 1987) whereas other workers concluded that thermotectonic effects along major structures were responsible for Ar loss and subsequent resetting of dates (Kontak et al., 1989; Kontak and Cormier, 1991). In general, K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronological data indicates the batholith cooled through temperatures of approximately 300-350°C at circa 370 Ma with later post-crystallization resetting in several areas throughout the batholith.

Age determinations obtained using U-Pb methods for zircon or monazite separates (Harper, 1980; Keppie et al., 1993) mainly yield circa  $370 \pm 5$  Ma ages for the various phases of the batholith, although it should be noted that the number of determinations is somewhat limited. An exception is the  $385 \pm 2$  Ma intercept U-Pb age for zircon from the Westfield deposit. Keppie et al. (1993) calculated a  $^{40}\text{Ar}/^{39}\text{Ar}$  plateau age of  $368.2 \pm 6$  Ma for a muscovite separate from fine-grained leucomonzogranite at the Westfield deposit. They concluded that the U-Pb zircon age represented time of crystallization ("closure temperature"  $> 750$ - $650^\circ\text{C}$ ) whereas the  $^{40}\text{Ar}/^{39}\text{Ar}$  muscovite age represented cooling through  $\approx 375$ - $400^\circ\text{C}$  ( $350^\circ\text{C}$  if data from McDougall and Harrison (1988) are used). However, the circa 20 My gap between crystallization and cooling

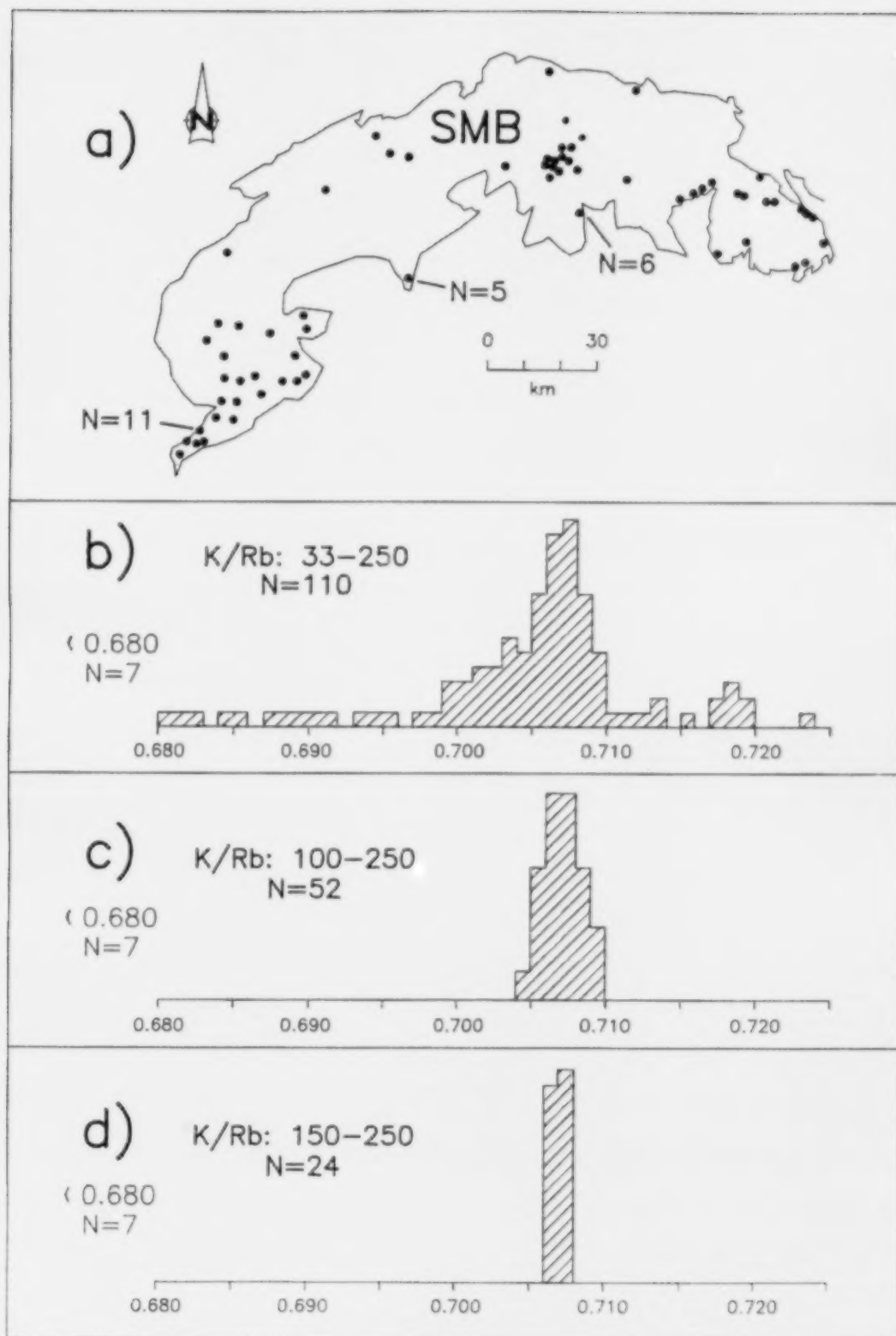


**Figure 7.3** Decay corrected initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios (time = 372 Ma) for 110 published analyses from the South Mountain Batholith (unpublished information, A.K. Chatterjee, 1993): a) sample location map; b) initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios for total data set (N=110) with K/Rb range from 33 to 250; c) initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios for samples with K/Rb ranging from 100–250 (N=52); d) initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios for samples with K/Rb ranging from 150 to 250 (N=24).

is considered to be somewhat unrealistic, particularly in light of the concordancy of all radiometric dates at circa 370 Ma. It is possible that the zircon age may represent incorporation of previously crystallized zircon during emplacement.

All of the reported Pb-Pb data denotes emplacement, crystallization and post-crystallization alteration/mineralization circa  $370 \pm 5$  Ma. Kontak and Chatterjee (1992) suggested their data recorded a mild overprinting of the Pb-Pb data circa 300 Ma but noted that their data were less conclusive than previous Rb-Sr and  $^{40}\text{Ar}/^{39}\text{Ar}$  studies. Hence, with the exception of the  $385 \pm 2$  Ma age from Westfield, all U-Pb and Pb-Pb derived ages are in accord. Therefore, the Pb isotopic system, unlike the Rb-Sr, K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  systems, was largely unaffected by resetting from either thermotectonism or fluid-driven isotopic re-equilibration.

Despite the restricted time of emplacement and crystallization, a systematic sequence of emplacement is evident throughout. First, Stage I plutons were emplaced. Chilled margins and other definitive contact relations among Stage I plutons are generally absent, although exposed contacts are rare. Stage II plutons were emplaced subsequent to Stage I intrusion. Several Stage I - Stage II pluton contacts were observed. With the exception of a gradational contact at the margin of the Halifax Pluton, all Stage I and II contacts appear to be intrusive in nature. None of the Stage II plutons has chilled margins, with the exception of a narrow zone ( $< 200$  m) along the northern contact of the East Dalhousie pluton and surrounding country rocks. The coarse-grained megacrystic units of the Stage II plutons were the first to crystallize. Contacts between these units were noted to be both intrusive and gradational. The emplacement of the fine-grained leucomonzogranite and leucogranite bodies appear to represent the final magmatic event, with the exception of a few fine-grained leucomonzogranite bodies that are in gradational contact with host megacrystic rocks (textural equivalents). The paucity of chilled margins indicates contemporaneous cooling of the various plutons, thus supporting the geochronological data. This factor, coupled with the lack of definitive contact relations at the major pluton boundaries, inhibits any further refinement of the overall emplacement history for the thirteen plutons.

It should be noted that although the arithmetic mean of most ages for the batholith cluster around 370 Ma, there are age discrepancies of several million years within most studies. For example the  $^{40}\text{Ar}/^{39}\text{Ar}$  ages for muscovite separates from leucogranites reported by Clarke et al.

(1993) actually range from  $369 \pm 2$  to  $375 \pm 4$  Ma. These ages may represent subtle differences in emplacement age, both within and between, individual Stage I and II plutons. In fact, it is possible that there are subtle variations in ages throughout the batholith that indicate its exact emplacement and/or cooling history. However, further geochronological studies, involving several isotopic systems, are required to fully unravel this sequence.



## Chapter 8

### NATURE AND ORIGIN OF THE BATHOLITH

#### 8.1 Introduction

The determination of the origin of granites is perhaps one of the most challenging problems faced by igneous petrologists, principally because granitic bodies, which commonly are formed by partial melting, are rarely at the same crustal level as their protoliths. Therefore, the establishment of source rock compositions for granitic bodies is mainly based upon a plethora of mineralogical, geochemical and isotopic evidence. A full and comprehensive treatment of the origin of the South Mountain Batholith is beyond the scope of this report and therefore brief summaries of the various lines of evidence for the origin of the batholith are presented in the following sections.

#### 8.2 Field Evidence

In previous Chapters it was noted that the batholith is in sharp intrusive contact with Paleozoic metasedimentary and metavolcanic country rocks. In most locations the associated thermal effects of these country rocks is minimal, the exception being the regular development of a narrow thermal aureole (ca. 100m to 1km wide) manifested by porphyroblastic growth of chiastolitic andalusite and cordierite. Other contact-related effects include the obliteration of slaty cleavage and silicification of country rocks. Development of migmatite zones is rare, being restricted to large roof pendants such as along the margin of the Kejimikujik Pluton (Horne, 1994) and near Boot Lake (MacDonald and Ham, 1992). These factors, coupled with the overall lack of deformation of country rocks and abundance of metasedimentary xenoliths in the biotite-rich units, indicate that the batholith was emplaced as a melt, magma or 'crystal mush' and principally intruded via a mechanism of stoping, at least at the present level of exposure. Therefore, based solely on field evidence, it is reasonable to disregard *in situ* melting or granitization of country rocks as a plausible mechanism of formation of the batholith. Accordingly, the plutons of the batholith must have originated by partial melting of a deeper protolith, followed by upward movement of magma to its level of emplacement.

One method of determining the composition of potential source rocks for the batholith

entails the examination of xenoliths, assuming that some may have originated from, or near, the zone of partial melting, and that these can be distinguished from assimilated country rocks. The abundance, morphology and macroscopic mineralogy of xenoliths were noted during field mapping. Some xenoliths have fine- to medium-grained equigranular or fine- to coarse-grained megacrystic igneous textures. Some 'igneous' xenoliths contain xenoliths of possible metasedimentary origin. Results from a petrographic study of xenoliths from throughout the batholith (Tate, 1994) indicated these microgranular igneous xenoliths have the same essential mineralogy as the main rock types of the batholith. Therefore they are tentatively interpreted as 'autoliths' from early-crystallized portions of the batholith that became incorporated into later melts. Tate (1994) also investigated surmicaceous enclaves in the batholith that might represent true restites, although the possibility that these xenoliths represented partial melting of included metasedimentary enclaves could not be ruled out based on available information.

The only 'exotic' xenolith (i.e., not from the country rock at present level of erosion) reported to date was observed in diamond drill core from the Big Indian Lake Pluton (Corey and Chatterjee, 1992). This xenolith contains garnet, clinopyroxene, plagioclase and titanite, and is remarkably similar to lower crustal granulite xenoliths encountered in the Tangier lamprophyre dyke in the eastern Meguma Zone (Giles and Chatterjee, 1987; Eberz et al., 1991). Measurements of  $X_{Fe}$  and  $X_{Mg}$  of titanite from this xenolith (M.C. Corey, personal communication, 1994) yield similar P-T estimates (approximately 15 kbar and 1100-1400°C) to those for the lower crustal Tangier xenoliths. The relevance of this 'exotic' xenolith, in terms of the origin of the entire batholith, will be discussed at the end of this chapter.

### 8.3 Mineralogical Evidence

The essential mineralogy of the major rock types of the South Mountain Batholith consists of quartz, alkali feldspar, plagioclase, biotite and muscovite with variable modal amounts of cordierite (0- > 5%), andalusite (0-2%), garnet (0-5%) and topaz (0-8%), as outlined in Chapter 4. This mineral assemblage is consistent with the S-type class of granites, as proposed by Chappell and White (1974). In particular, the significant modal amounts of cordierite in many monzogranite and leucomonzogranite units satisfies an important mineralogical requirement for S-type granites. Chappell and White (1974) concluded that S-type granites were formed via the melting of predominantly metasedimentary rocks, hence the 'S' denotation, in contrast to I-type granites that originated either from the partial melting of dominantly igneous rocks or from fractionation of

mantle melts. Clarke (1992; and references therein) concluded that the 'alphabet classification of igneous rocks' is fraught with problems and inconsistencies and should be treated with some degree of trepidation. In particular he noted that the letters I and S may only indicate the dominant source material and do not eliminate the possibility of composite source regions, possibly with a mantle input.

The mineralogy of the batholith is consistent with the 'characteristic mineralogy' of peraluminous granites, as outlined by Clarke (1981). However, peraluminous granites can be generated by several processes including fractional crystallization of metaluminous or I-type granites (Clarke, 1981; Zen, 1986), although resulting granites are rarely the size of the South Mountain Batholith. Therefore, conclusions about source rock composition based solely upon the peraluminous nature of the batholith would be suspect.

Ilmenite is the common opaque oxide phase in the batholith. In fact, the only magnetite identified in the entire batholith consists of an occurrence of albite-magnetite breccia in a drill hole in the Davis Lake Pluton (Richardson, 1988), which is interpreted to result from deformation and hydrothermal alteration of coarse-grained leucomonzogranite (MacDonald et al., 1992). The ubiquitous occurrence of ilmenite throughout the batholith, coupled with the presence of muscovite and low Mg/Fe biotite, is consistent with the ilmenite-series of granitic rocks as defined by Ishihara (1977). These rocks were interpreted as originating from partial melting in the middle to lower regions of the continental crust, with possible interaction with C-bearing metasedimentary rocks during generation and/or emplacement (Ishihara, 1977).

In summary, the mineralogical evidence indicates that the South Mountain Batholith was generated by the melting of predominantly metasedimentary source rocks, although the possibility of interaction with, or contribution from, other crustal rocks or possibly mantle-derived magma cannot be dismissed on mineralogical evidence alone.

#### 8.4 Geochemical Evidence

As noted in Chapter 5, all rocks of the batholith are peraluminous ( $\text{molar Al}_2\text{O}_3 / (\text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O}) > 1$ , i.e.  $A/\text{CNK} > 1$ ). In fact, average compositions for the major rock types in both Stage I and II plutons have  $A/\text{CNK}$  values in excess of 1.1 and, therefore, satisfy the basic chemical prerequisite for S-type granites (Chappell and White, 1974).

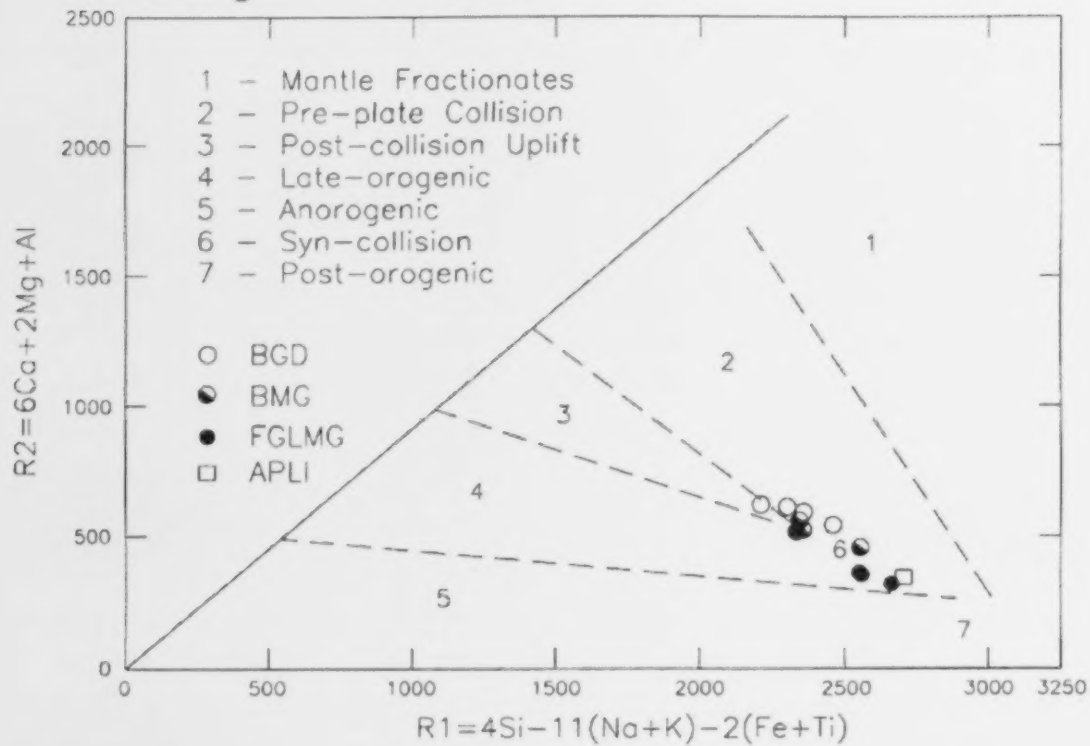
Average major and trace element data for Stage I and Stage II plutons were plotted on several tectonic discriminating diagrams (e.g. Pearce et al., 1984; Whalen et al., 1987; Batchelor and Bowden, 1985). The large variation in trace element content from biotite granodiorite to leucogranite results in the rock types from the batholith plotting in several tectonic environments including volcanic arc, syn-collisional and within plate granites (Pearce et al., 1984) fractionated felsic and orogenic granites (Whalen et al., 1987). Biotite granodiorite and biotite monzogranite mainly plot in the orogenic and syn-collisional tectonic environments on the above diagrams. Data from Stage I and II plutons were plotted on the discriminating diagram of Batchelor and Bowden (1985) and are given in Figure 8.1. With the exception of the highly fractionated leucomonzogranites and leucogranites, all rocks plot in the syn-collisional field of their diagram. In short, the batholith is interpreted to have been generated in a syn- or late-collisional tectonic environment.

In a general sense, the high concentration of large ion lithophile elements (LILE, e.g. Rb, U, F, Li) and the low levels of Ni, Co, Cr and many other high field strength elements (HFSE) elements is consistent with a predominantly crustal source for the batholith. However, this observation is somewhat simplistic in light of the wide range of factors governing the solubilities of these elements in peraluminous melts, and the myriad of conditions (e.g. P, T, aH<sub>2</sub>O, fO<sub>2</sub>) that could effect the distribution of these elements.

#### 8.5 Stable Isotope ( $\delta\text{O}^{18}$ , $\delta^{34}\text{S}$ ) Evidence

There have been several **oxygen isotopic** studies of the batholith during the past two decades. Longstaffe et al. (1980) reported  $\delta\text{O}^{18}$  values for 127 whole-rock samples and coexisting minerals from the granitoid and metasedimentary rocks of the Meguma Zone. In determining  $\delta\text{O}^{18}$  values for representative compositions from the central and eastern portions of the batholith, Longstaffe et al. (1980) noted that the whole-rock  $\delta\text{O}^{18}$  values for the batholith generally ranged from +10.1 to +12.0‰ and noted the coexisting mineral phases were in equilibrium, indicating the whole-rock values were representative of "the magma". They concluded that the batholith was

## Stage I Plutons



## Stage II Plutons

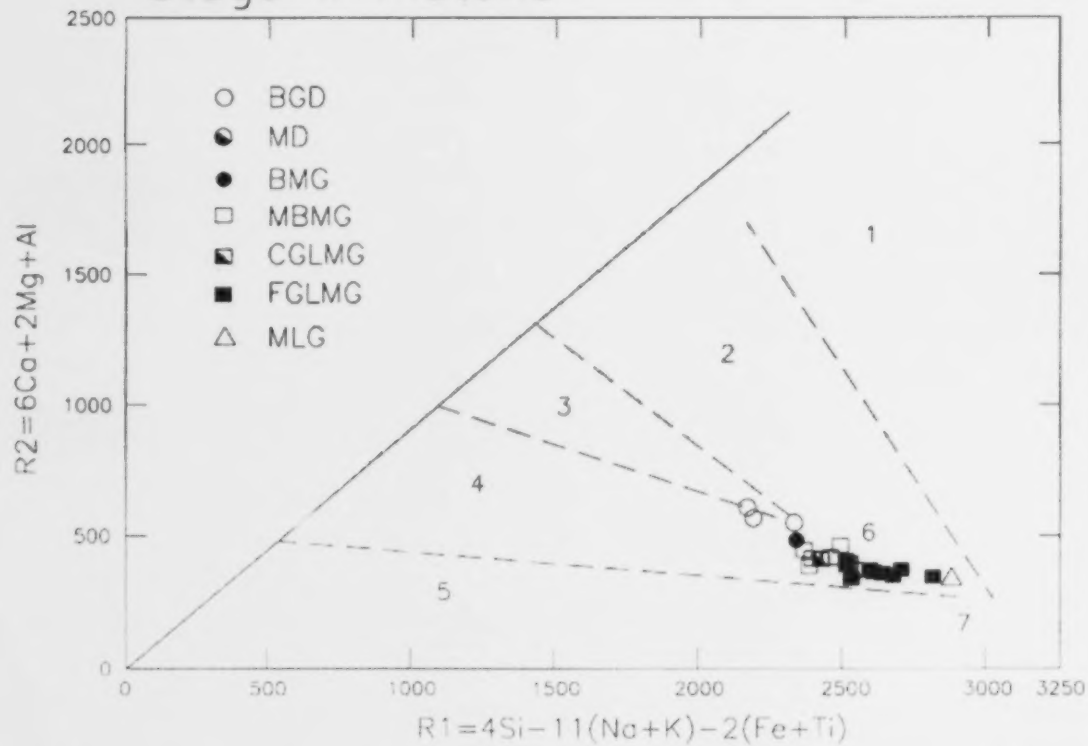


**Figure 8.1** Average rock compositions from Stage I and II plutons, plotted on the tectonic discriminating diagram from Batchelor and Bowden (1985). See text for discussion.



generated by melting of  $\delta\text{O}^{18}$ -rich metasedimentary rocks. Two whole-rock samples from the East Dalhousie-New Ross area of the batholith had  $\delta\text{O}^{18}$  values of +7.8 and +9.6‰. The exact explanation for these low values was not elucidated, however, similar  $\delta\text{O}^{18}$  results in the Brenton Pluton were interpreted as being caused by exchange with low  $\delta\text{O}^{18}$  fluids during shearing.

Chatterjee and Strong (1985) reported  $\delta\text{O}^{18}$  analyses for several unmineralized suites that primarily returned values of ca. +10 to +12‰, in agreement with the results of Longstaffe et al. (1980). They also analysed sample from the Millet Brook and East Dalhousie U deposits and polymetallic Sn mineralization from the East Kemptville Mine and other occurrences in the Southern Nova Scotia Tin Domain. They noted very high  $\delta\text{O}^{18}$  values for mineralized samples from U deposits (ca. +12 to +15‰) which they interpreted to represent mixing of magmatic and metamorphic (calcareous?) fluids. They also documented low  $\delta\text{O}^{18}$  values (ca. +6.5 to +10.0‰) for two suites of samples from intra- and peri-batholithic greisen suites in southwestern Nova Scotia that were interpreted to represent interaction between meteoric and magmatic fluids.

Kontak et al. (1988) measured the  $\delta\text{O}^{18}$  compositions for a suite of fourteen samples of leucomonzogranite and leucogranite samples from the eastern portion of the batholith. They noted that most samples had uniform  $\delta\text{O}^{18}$  concentrations of  $+10.6 \pm 0.5$ ‰ with no systematic variation with proximity to metasediment contacts. They concluded that deviations in mineral separates reflected re-equilibration of feldspars with late-magmatic, low-temperature fluids. One sample of quartz-muscovite greisen from the contact zone of the Halifax Pluton (+11.5 to +14.0‰ for 300°-400°C) was interpreted as reflecting interaction with a 'heavy' metamorphic fluid. In contrast, a sample from near the East Dalhousie Fault Zone with  $\delta\text{O}^{18} = +3.6$ ‰ was interpreted as reflecting interaction with meteoric fluids. Interestingly, this sample was collected proximal to samples from Longstaffe et al. (1980) with the lowest concentrations of  $\delta\text{O}^{18}$ . Kontak et al. (1991) presented more  $\delta\text{O}^{18}$  data for the same sample suite and confirmed the initial results of Kontak et al. (1988).

Kontak (1990a) reported  $\delta\text{O}^{18}$  data for six whole-rock samples from the East Kemptville leucogranite. The entire sample suite had whole-rock  $\delta\text{O}^{18}$  values that ranged from +8.2 to +12.2‰ with an average value (N=5) of  $8.96 \pm 0.71$ ‰. The high whole-rock  $\delta\text{O}^{18}$  value in one sample of dyke rock was interpreted as reflecting non-fractional crystallization processes. Kontak



(1990) concluded that the  $\delta\text{O}^{18}$  data were consistent with other published data from the batholith and supported the generation of the East Kemptville leucogranite via partial melting of crustal rocks including sedimentary and/or modified plutonic/volcanic rocks that once resided at the earth's surface.

Poulson et al. (1991) reported  $\delta\text{O}^{18}$  values for quartz and feldspar separates from a suite of 21 samples of granodiorite from the contact zone at Mt. Uniacke (Corey, 1987). They noted that  $\delta\text{O}^{18}_{\text{Quartz}}$  values (av +12.24‰, range +11.93‰ to +12.54‰) were comparable to previously published values (e.g. Longstaffe et al., 1980) for other parts of the batholith. They noted that disequilibrium occurred between  $\delta\text{O}^{18}$  results for quartz and feldspar in a few samples and concluded that this probably represented isotopic exchange, mainly between feldspar from these samples and a fluid phase, possibly a low temperature meteoric water.

Clarke et al. (1993) measured whole-rock  $\delta\text{O}^{18}$  values for a suite of 47 leucogranite samples from the eastern portion of the batholith. The entire data set ranged from +7.71 to +15.04‰ with an average composition of  $+11.4 \pm 1.01$ ‰ (1 sigma); 42 of the 47 samples lay between +10.1 and +12.7‰. They noted that these results were very similar to the previous studies and reflected the dominance of  $\delta\text{O}^{18}$ -rich supracrustal protolith(s). Interestingly, the lowest  $\delta\text{O}^{18}$  concentration (+7.71‰) was for a sample from near the East Dalhousie Fault Zone, whereas the highest value (15.0‰) was for a sample from near the Millet Brook U deposit. In both cases these results resemble previously reported  $\delta\text{O}^{18}$  values from these same general areas of the batholith studies.

Taylor (1988) concluded that granitic rocks with high  $\delta\text{O}^{18}$  values ( $\delta\text{O}^{18} > +8.0$ ‰) **require** "...the involvement of some precursor parent material that at some time in the past resided on or near the Earth's surface, either as sedimentary rocks or as weathered or hydrothermally altered rocks". These rocks could represent either the dominant protolith composition or a chemical/isotopic reservoir encountered by the granitic rocks *en route* to the level of emplacement. Therefore, the  $\delta\text{O}^{18}$  data for the batholith indicate it was generated by melting of  $\delta\text{O}^{18}$ -rich supracrustal rocks. Relatively higher and lower  $\delta\text{O}^{18}$  values (i.e.  $< \text{ca. } +9$ ‰ and  $> \text{ca. } +13$ ‰, respectively) indicate interaction with  $\delta\text{O}^{18}$ -rich (e.g., metamorphic) and  $\delta\text{O}^{18}$ -depleted (e.g., meteoric) fluids during, or subsequent to, crystallization.

Kontak (1990b) determined the **sulphur isotopic** compositions of a suite of 31 sulphide samples (pyrite, pyrrhotite, sphalerite, chalcopyrite, arsenopyrite, galena) from the tin- and base-metal stages of mineralization at the East Kemptville deposit. He noted a very restricted range of  $\delta^{34}\text{S}$  from +3.6 to +6.6‰ and concluded that these sulphide phases originated from a common magma-derived fluid with a  $\delta^{34}\text{S}$  value of  $+5.0 \pm 0.5$ ‰. Kontak (1990b) concluded that there was "...negligible contribution of heavy sulphur from the Meguma Group". However, Kontak (1993) concluded that mobilization of sulphur from the Meguma Group could explain extreme variation in  $\delta^{34}\text{S}$  (-8.8 to +55‰) in a suite of samples from the late-stage zeolite-bearing mineralization at East Kemptville. This conclusion is in accord with the results of an earlier study by Kubilius (1983) where isotopic equilibration between the batholith and Meguma Group country rocks was postulated to explain observed variations in  $\delta^{34}\text{S}$ . Kontak (1990b) concluded that isotopic data indicated the sulphur in the East Kemptville deposit was dominantly of crustal derivation, although the possibility of sulphur contribution from mantle magma(s) or fluid(s) could not be ruled out.

Poulson et al. (1991) conducted a sulphur isotopic study of a suite of samples from the entire batholith and surrounding country rocks, and also for a suite of samples from the granite/metasediment contact zone at Mt. Uniacke. They noted that  $\delta^{34}\text{S}$  values for the Meguma Group metasedimentary rocks ranged from -3.7 to 26.3‰. They concluded that approximately 30-60% of the sulphur (av.  $\approx 20$  ppm for Stage I plutons;  $\approx 300$  ppm for Stage II plutons) was present in pyrrhotite, whereas the remainder occurred as substitutions in biotite structure.  $\delta^{34}\text{S}$  values were noted to range from +5.4 to +8.4‰ for Stage I plutons and +1.6 to +15.0‰ for Stage II plutons. Most samples from the contact zone at Mt. Uniacke had higher  $\delta^{34}\text{S}$  values (+6.6 to +12.3‰) than 'regional' granodiorite samples of other Stage I plutons. Conversely, some hydrothermally altered granodiorite samples were noted to have much lower  $\delta^{34}\text{S}$  values (+0.45 to +0.67‰). Poulson et al. (1991) concluded that fractional crystallization combined with assimilation (AFC) of isotopically variable Meguma Group metasedimentary rocks best explained their  $\delta^{34}\text{S}$  results. Furthermore, they suggested that the AFC processes may have involved either bulk assimilation of Meguma Group rocks or selective desulphidation of country rocks and enclaves.

#### 8.6 Radiogenic Isotope (Sr, Nd, Pb) Evidence

A summary of published **strontium isotopic** studies was presented in Chapter 7. The results from these investigations indicated a wide range of initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios from low and intermediate values (ca. 0.680, A.K. Chatterjee, unpublished data, 1994; 0.7076-0.71021, Clarke and Halliday, 1980) in most of the batholith to higher values (0.727, Richardson et al., 1989; 0.729 Kontak and Cormier, 1991) in the Davis Lake Pluton. However, as noted in Chapter 7, the wide variation in initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios only persists when "altered" samples with  $\text{K/Rb} < 150$  are included. The range of initial  $^{87}\text{Sr}/^{86}\text{Sr}$  for a suite of "unaltered" samples ( $\text{K/Rb} > 150$ ) was noted to be 0.706 to 0.708. Richardson et al. (1990) documented extreme variation in initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios (0.7135 to 0.8284) for hydrothermal fluorite and phosphate minerals from the East Kemptville tin deposit. Their data clearly signified the presence of a fluid with high initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, thus supporting the thesis that the Rb-Sr isotopic system was influenced by late- to post-magmatic fluids.

Taylor (1988) noted that granites with initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in excess of 0.706 were generated from the melting of supracrustal metasedimentary rocks, eugeosynclinal volcanogenic sediments or altered volcanic rocks. Chappell and White (1974) stated that S-type granites characteristically have initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios greater than 0.708, in contrast to I-type granites with values of 0.704-0.706. The initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios for rocks with  $\text{K/Rb} > 150$  all lie in the gap between the S- and I-type granites of Chappell and White (1974).

Clarke et al. (1988) conducted a **neodymium isotopic** study of the granitoid rocks of the batholith. They analysed a suite of granodiorite, fine- and coarse-grained leucomonzogranite from the central part of the batholith, along with metasedimentary xenoliths and host granodiorite from the contact zone near Mt. Uniacke. They compared their results with earlier Sm-Nd and Rb-Sr isotopic studies of the country rocks and the South Mountain Batholith respectively (Clarke and Halliday, 1980; 1985) to ascertain the possible genetic links between them. They noted that the batholith had  $\epsilon\text{Nd}^t$  ( $t=372$  Ma) values ranging from -5.2 to -1.4 that were significantly higher than those of the Meguma Group rocks (-11.2 to -8.7). Hence, they concluded that the protolith for the batholith was not the Meguma Group, although they documented isotopic re-equilibration between the xenoliths and host granodiorite. Furthermore, based upon the  $\epsilon\text{Nd}^t$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  data, Clarke et al. (1988) proposed that the South Mountain Batholith was generated by melting of a

deeper crustal source than the Meguma Group, possibly accompanied by (i.e., mixing with) input from mantle-derived magma.

Chatterjee and Ham (1991) reported **lead isotopic** concentrations for a suite of samples from the entire South Mountain Batholith. They concluded that the batholith was derived from melting of granulite rocks with possible contamination from Liscomb gneisses and overlying Meguma Group rocks prior to final emplacement and crystallization.

Kontak and Chatterjee (1992) conducted a Pb isotopic study of a suite of samples from the East Kemptville leucogranite and associated polymetallic greisens. They reported a  $\mu$  value of 9.75 for these samples and concluded that this was evidence for an evolved upper crustal source region for the batholith, as opposed to a lower crustal granulite source.

### 8.7 Summary and Discussion

It is apparent from the field evidence that the South Mountain Batholith was emplaced as a melt or, more likely, as a partially solidified crystal mush by stoping, which had only minimal contact-related effects on the country rocks. Mineralogical, chemical and isotopic constraints dictate that the protolith(s) for the batholith was of supracrustal origin with a significant metasedimentary rock component. However, the possible mixing or interaction with mantle-derived mafic magma and or assimilation of country rocks cannot be ruled out.

Recent work in the eastern Meguma Terrane now provides insight into its crustal stratigraphy at ca. 370 Ma. Giles and Chatterjee (1986, 1987) reported an ortho- and paragneiss complex with associated quartz gabbro, granite and leucogranite intrusions that pierced the Meguma Group metasedimentary rocks near Liscomb. Geochronological studies ( $^{40}\text{Ar}/^{39}\text{Ar}$ ) of the gneissic rocks (Kontak et al., 1990) indicate that they were emplaced in the waning stages of the Acadian Orogeny (ca. 370 Ma) along with the major granitoid plutons. Clarke et al. (1993) reported T-P estimates for the gneissic rocks that ranged from 760°C and 6.4 kbar to 980°C and 8.2 kbar. They also noted that some petrological disequilibrium features (e.g., mineral zoning and corona structures) were indicative of fluctuating P-T conditions that reflected the rapid emplacement of the gneiss dome ca. 370 Ma. Clarke et al. (1993) concluded that the mafic intrusions in the Liscomb Complex were of within-plate or volcanic arc origin and were derived from slightly depleted mantle sources.



Ruffman and Greenough (1990) reported on the occurrence of a mafic dyke swarm, termed the "Weekend dykes", that outcrop in the eastern Meguma Terrane (Fig. 1.2). They noted that approximately half of the dykes contained exotic gneissic and (meta)plutonic xenoliths. Kempster et al. (1989) reported  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of  $370 \pm 2$  and  $367 \pm 2$  Ma for two of the Weekend dykes in the vicinity of Tangier which suggested that the dykes may have been emplaced synchronously with the mafic magmas of the Liscomb Complex. Chatterjee and Giles (1988), Eberz et al. (1988) and Eberz et al. (1991) conducted detailed petrological and geochemical studies of a suite of granulite xenoliths from one of these dykes near Tangier, with lamprophyric composition. These workers reported several types of xenoliths with varying modal proportions of sapphirine, garnet, spinel, orthopyroxene, clinopyroxene and amphibole. Chatterjee and Giles (1988) reported maximum P-T estimates for the Tangier xenoliths of 14.2-14.8 kbar and 1030-1066°C and noted that other P-T estimates from the xenolith suite recorded rapid decompression and heating after incorporation into the ascending Tangier dyke. Eberz et al. (1991) concluded that the Tangier xenoliths represent average to upper crustal model compositions and were tentatively interpreted as subducted Avalon Terrane.

The recent documentation of high metamorphic grade rocks in both the Liscomb Complex and Tangier dyke, provides two "windows" to deeper crustal regions of the Meguma Zone ca. 370 Ma, and hence provides the opportunity to evaluate deep crustal source regions for Meguma Zone granitoid rocks.

The crustal stratigraphy ca. 370 Ma consisted of Meguma Group upper crustal rocks overlying Liscomb Terrane which, in turn, was underlain by Tangier (Avalon?) Terrane. Eberz et al. (1991) and Clarke et al. (1993) presented Nd-Sm isotopic data for xenoliths from the Tangier dyke and gneisses from the Liscomb Complex, respectively, and compared their data with published results for the Meguma Group rocks (Clarke and Halliday, 1985). These workers proposed that the crustal stratigraphy in the Meguma Zone ca. 370 Ma was "inverted" with "crustal residence ages" decreasing from the "oldest" Meguma Group (1170-1450 Ma) to the "younger" Liscomb gneisses (403-627 Ma) and Tangier xenoliths (ca. 600 Ma).

All three proposed terranes are possible source regions for the generation of the South Mountain Batholith. Each of these terranes will now be evaluated individually:

## 1) Meguma Group

Longstaffe et al. (1980) concluded that the batholith could be generated from anatexis of the Meguma Group metasediments, based on  $\delta O^{18}$  data. Conversely, Clarke and Halliday (1980) compared the strontium isotopic compositions of the batholith and the Meguma Group rocks and concluded that the initial ( $^{87}Sr/^{86}Sr$ )<sub>372</sub> ratios of early-crystallized granodiorite (0.7081) were distinctly lower than any of the analysed metasedimentary rocks and consequently the granodiorite, and presumably the batholith as a whole, was not formed by partial melting of these rocks alone. Clarke et al. (1988) measured the neodymium isotopic composition of the batholith and compared the results with data from the Meguma Group rocks (Clarke and Halliday, 1985). They noted that the batholith had epsilon Nd<sup>t</sup> values (-5.2 to -1.4) that were considerably higher than values in the Meguma Group (-11.2 to -8.7) and subsequently proposed that the Meguma Group was not a suitable protolith for the batholith.

Isotopic (i.e., Sr, Nd, S) and, presumably, bulk chemical contamination of the batholith by Meguma Group rocks has been documented by Clarke and Halliday (1980), Kubilius (1983) and Clarke et al. (1988), although quantification of the amount of isotopic exchange remains unknown. These factors could influence the determination of source rock composition, however, the removal of these effects would not change the conclusion that the Meguma Group rocks are not suitable protoliths for the batholith.

## 2) Liscomb Gneisses

Clarke et al. (1993) concluded, on the basis of geochemical and isotopic information that the granites from the Liscomb Complex are similar to other granite bodies in the Meguma Zone. In fact, they noted that these granites isotopically overlap both the South Mountain Batholith and the intermediate gneisses of the Liscomb Complex. They subsequently proposed that other Meguma Zone granitoids could be generated by similar processes as evoked for the Liscomb Complex, that is underplating and partial melting of Liscomb gneisses to form the granitic rocks. In this scenario, slight compositional differences between the plutons of batholith and the Liscomb granites would represent compositional variations in the actual protoliths. Clarke et al. (1988) indicated that the source rocks for the batholith must have "younger" crustal residence ages, as defined by neodymium isotopes, than the Meguma Group rocks. As noted above, the Liscomb



gneisses satisfy this criteria and must be considered a possible source for the batholith.

### 3) Tangier granulites

As stated above, mineralogical, geochemical and isotopic studies (Chatterjee and Giles, 1988; Eberz et al., 1988; Eberz et al., 1991) indicate that the exotic xenoliths from the Tangier lamprophyre dyke have compositions consistent with upper crustal rocks and, therefore, are potential protoliths for the batholith. Eberz et al. (1991) noted that the neodymium and strontium isotopic compositions of the granulite xenoliths qualified them as potential sources for the batholith. Clarke and Chatterjee (1992) concluded that the granulite facies metasedimentary xenoliths from the Tangier dyke are the most suitable protolith for most peraluminous granites of the Meguma Zone including the South Mountain Batholith, but not the Liscomb granites as outlined above.

In summary, the plutons of the batholith are interpreted as resulting from partial melting of either the Tangier or Liscomb "terrane", or possibly a combination of the two, beneath the Meguma Terrane. Underplating of either terrane by mantle-derived magma may have contributed to the generation large volumes of granite magma ca. 370 Ma. However, unlike the Liscomb Complex, significant amounts of gabbro and diorite intrusions are absent in the South Mountain Batholith and much of the Meguma Zone. Slight mineralogical and geochemical differences between the various plutons may simply reflect compositional variation within these terranes.

*Chapter 9***ECONOMIC GEOLOGY****9.1 Introduction**

The South Mountain Batholith is host to the past-producing East Kemptville (Sn-Zn-Cu-Ag) and New Ross Manganese (Mn-Fe-P) Mines, the Millet Brook (U-Cu-Ag) deposit and numerous polymetallic prospects and occurrences. Several workers including Chatterjee (1980) and Chatterjee and Strong (1984) noted similarities in the geological setting, petrochemistry and style of mineralization and attending alteration of the Meguma Zone granitoid bodies and Hercynian granites of central and western Europe and other worldwide Paleozoic and Mesozoic fold belts. In light of the gregarious nature of worldwide granophile deposits, Giles and Chatterjee (1984) proposed that the discovery of the East Kemptville deposit was possibly the "tip of the iceberg" for mineral potential in the Meguma Zone. The primary goal of the South Mountain Batholith project, conducted as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement, was the evaluation of the mineral potential of the batholith through geological mapping.

All known mineral deposits and occurrences were investigated, and numerous new occurrences were found, during the course of this project. Brief descriptions for all occurrences are given in the marginal notes that accompany the fourteen 1:50,000 scale geological maps listed in Figure 2.1. Essential information for each mineral occurrence including location, commodities, deposit type and map sheet reference have been tabulated and are presented in Appendix B. In addition to these brief descriptions, several occurrences have been mapped and/or sampled for further petrographic and geochemical study. The results of these investigations are outlined in several reports by Departmental staff including Corey (1988b), Finck et al. (1988), MacDonald and O'Reilly (1989), Corey and Horne (1989c), O'Reilly (1992), O'Reilly et al. (1992) and references therein.

This section of the report includes: a brief description of the exploration history in the batholith; an overall classification scheme for mineralization, based upon data from this study; and some observations regarding the age, distribution and various factors that govern the distribution of mineralization in the batholith.

## 9.2 Exploration History

In the early 1900s most mineral exploration centred on the potential for gold in the metasedimentary rocks of the Meguma Group (Malcolm, 1976; Bates, 1987). Despite this predominance of gold exploration, sporadic base metal exploration has been conducted in the South Mountain Batholith for more than a century. A summary of the overall exploration trends, with major exploration and discovery milestones, is presented here.

The first reported mineral occurrences in the batholith were mainly in the New Ross area and were found by early settlers. Occurrences include the Keddy prospect (Mo-Ta-Nb), where test pits were first excavated in 1890, and the Reeves tin pit (Sn-W-Ta-Nb-F), which was originally prospected in 1903 (O'Reilly *et al.*, 1982). Other prospects in the New Ross area include the Turner tin prospect (Sn-Cu-W-Zn), found in 1908, and the Walker molybdenite prospect (Mo-W-Sn-U-Cu-Ag-Mo-Bi), which was discovered in 1911 (Farley, 1978). Detailed descriptions of many of the early discovered prospects are given in O'Reilly *et al.* (1982), Charest (1976), Farley (1978), Logothetis (1985) and Charest *et al.* (1985). Pits and shafts were excavated at many of these occurrences for the purpose of bulk sampling; however, no mine production has been reported for any of these prospects.

In addition to the New Ross discoveries an occurrence of copper (chalcopyrite and chalcocite) in a quartz vein at Alton in Kings County was first found in 1876. A shaft was sunk at this occurrence but no production has been reported (Faribault, 1920).

Fault-controlled Mn-Fe minerals were first discovered north of the New Ross area in 1891, leading to the development of the Cain and Riddle Mine in the late 1890s. A second discovery of Mn-Fe in 1907 led to the development of the Dean and Chapter Mine approximately 3 km from the Cain and Riddle Mine. Production at the two mines, collectively termed the New Ross Manganese Mines, continued sporadically until 1940 when the last ore was mined for the war effort. Since then the only Mn-related activities in the batholith include bulk sampling at the former Cain and Riddle Mine in 1958 and limited reconnaissance work in the New Ross area in the early 1980s (O'Reilly, 1992).

Much of the central part of the batholith was mapped by the Geological Survey of Canada between 1900 and 1930. Numerous mineral occurrences were discovered, including: Morley's pegmatite (W-Sn-Be-Ta-Nb-Li; Faribault, 1908); Long Lake deposit (Mo-W-Be-Cu-As-F); Lake

Darling (Cu) and Nevertell Lake (Sn-W; Faribault, 1924); and Lake Ramsay (Zn-Sn-Au-Mo-Cu) and the Wallaback Lake Sn occurrence (also called Grassy Brook; Faribault, 1931). Most of the previously discovered deposits, including those in the New Ross area and the Westfield deposit, were also investigated during these regional mapping programs (O'Reilly *et al.*, 1982; O'Reilly, 1985).

Following these early mineral exploration activities, there was very limited exploration, primarily centred in the New Ross area and including the work of Douglas and Campbell (1942) and Wallace *et al.* (1963; see O'Reilly *et al.* (1982) for complete summary). The low level of exploration activity continued until 1976 when mineralized metasedimentary boulders (Sn-Zn-Cu-Ag) were discovered in newly excavated road fill near Yarmouth by prospector Merton Stewart while working for Maritime Exploration Limited. This discovery led to extensive exploration by numerous companies including Shell Canada, who discovered the East Kemptville Sn-Zn-Cu-Ag deposit in 1978 (Richardson *et al.*, 1982). This mine had initial reserves of 56 million metric tonnes grading at 0.165% Sn (Moyle, 1985). The mine was put into production as a 10,000 ton per day open pit mine in October 1985 and operated until January 1992 when the mine ceased operations because of economic reasons. Total production for the mine was 21 350 t Sn, 1 582 t Cu, 2 008 t Zn and 201.82 kg Ag (Kontak, 1994).

The discovery of polymetallic tin deposits in the southwestern part of the batholith touched off a major base metal exploration 'boom' that continued until the early 1980s. Numerous occurrences were discovered throughout the batholith including important discoveries near Upper New Cornwall (Corey, 1983), Caledonia (MacGillivray, 1982), Bezanson Lake (Sinclair *et al.*, 1980) and Little Tobeatic Lake (Dickie and Zwicker, 1983).

Concurrent with this burst of base metal exploration was a major exploration 'boom' for uranium. This activity was partially in response to the energy crisis of the 1970s. One of the principal catalysts for uranium exploration was the production of airborne gamma-ray spectrometric surveys (5 km spacing) over the Meguma Zone (Geological Survey of Canada, 1977). These surveys enabled exploration companies to focus their attention on highly evolved or 'specialized' leucomonzogranite and leucogranite rock units that commonly host uranium deposits worldwide. Spectrometric surveys also proved useful for delineating uranium concentrations in lesser evolved granitic rocks.

Exploration activities by Acquitaine Company of Canada Ltd. led to the discovery of the Millet Brook U-Cu-Ag deposit in 1978 (Chatterjee *et al.*, 1982). Diamond-drilling indicated total reserves of approximately 1.0 million pounds of  $U_3O_8$  with an average grade of 0.15 - 1.20%  $U_3O_8$  over a 2.0 m width (Chatterjee *et al.*, 1985). Numerous other vein-type  $U \pm Cu \pm Ag \pm P \pm F$  occurrences were discovered throughout the batholith including the Gaspereau Lake (also named Aylesford Lake) occurrence (Low and Farstad, 1978a) and the East Dalhousie occurrence (Lowe and Farstad, 1978b) which were found by Esso Minerals Canada. Shell Canada focused much of their uranium exploration activity along the northern margin of the batholith, resulting in the discovery of several mineral occurrences, including those at Randall Lake (St. George, 1982; MacDonald and Ham, 1992), Inglisville Church (Dickie and Jensen, 1981; MacDonald and Ham, 1989b), Shortliff Lake (Dakers, 1982; MacDonald and Ham 1989a) and Lambs Lake (Dakers, 1982; Corey and Horne, 1989a). All uranium exploration activities in the batholith, including the development-related work at Millet Brook, were terminated by a province-wide uranium moratorium announced by the Government of Nova Scotia on September 21, 1981. The moratorium was still in effect at the time this report was prepared.

There has been minimal mineral exploration in the South Mountain Batholith since 1982. The most notable exception was the production- and exploration-related work at, and near, the East Kemptville mine, which was terminated in 1992. Also, there has been limited exploration for base metals and precious metals in the southwestern Nova Scotia tin domain (see discussion below).

### 9.3 Mineral Deposit Types

Mineral deposits of the South Mountain Batholith have been classified into five main groups: greisen, vein, breccia, pegmatite and peribatholithic deposits. The distribution of these deposit types is shown in Figure 9.1. A schematic diagram outlining the modes of occurrence of the main deposit types, including orientation of ore zones, proximity to granite-metasediment contacts, and host rocks, is given in Figure 9.2 and summarized in Table 9.1. Summaries of each deposit type, and brief descriptions of important occurrences, are given in the following sections.

#### 9.3.1 Greisen Deposits (Sn, W, Mo, As, Cu, Pb, Zn, F, Au, Ag)



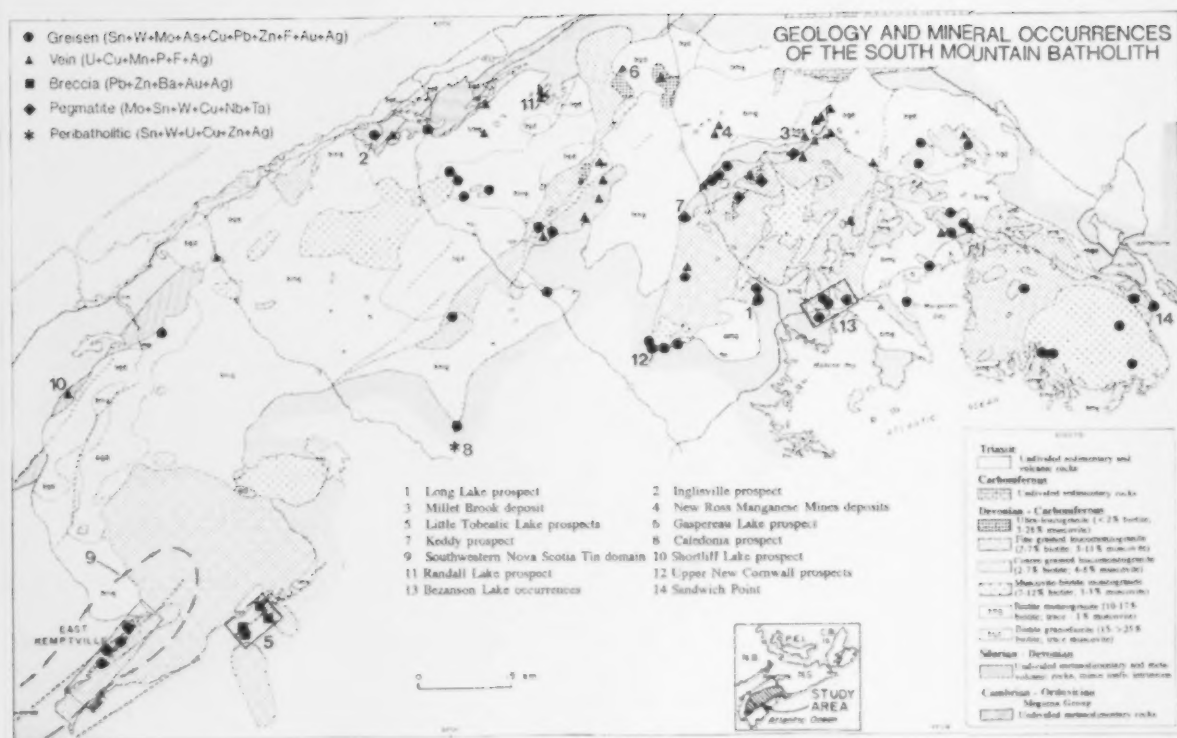
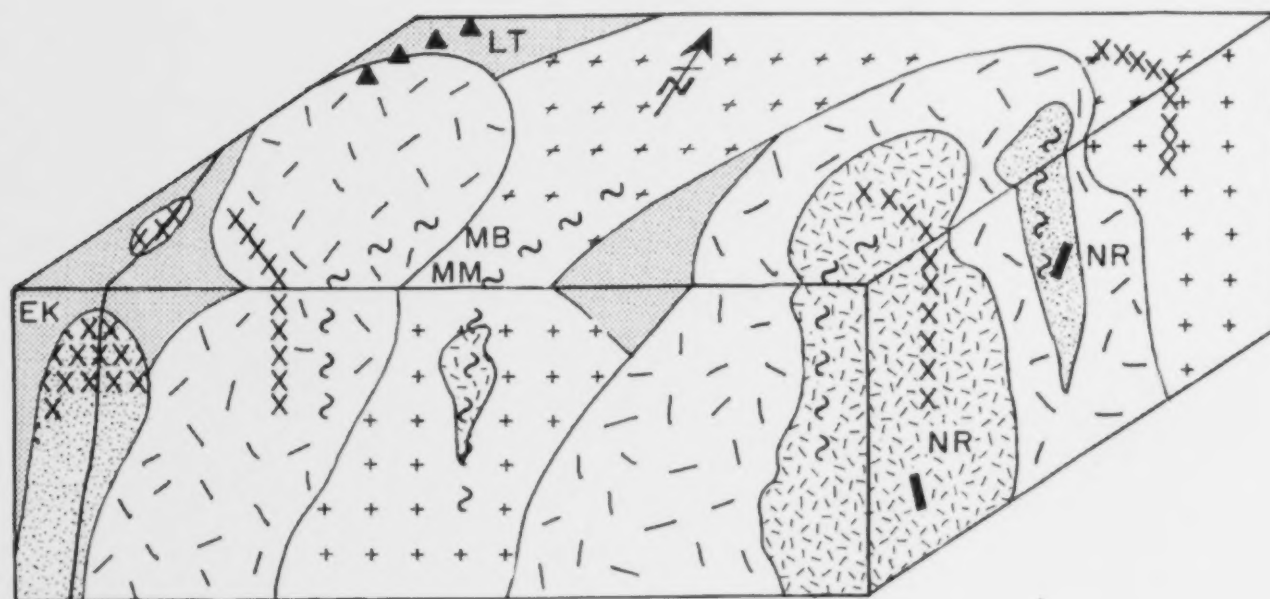


Figure 9.1 Geological map of the South Mountain Batholith showing the distribution of the major rock types. The location and type of all mineral deposits and occurrences are also indicated.



## LEGEND

### DEVONIAN

#### STAGE II PLUTONS

-  muscovite  $\pm$  topaz leucogranite
-  fine-grained leucomonzogranite
-  coarse-grained leucomonzogranite & muscovite-biotite monzogranite

#### STAGE I PLUTONS

-  biotite, monzogranite & biotite granodiorite

### CAMBRO-ORDOVICIAN

-  Meguma Group

## DEPOSIT TYPES

- Greisen (EK - East Kemptville) . . . . . 
- Vein (MB - Millet Brook; MM - Manganese Mines). . . ~ ~
- Pegmatite (NR - New Ross) . . . . . 
- Breccia (LT - Little Tobeatic Lake). . . . . 

## SYMBOLS

- Fault . . . . . 

Figure 9.2 Schematic diagram outlining the distribution of the five deposit types in the Stage I and II plutons of the batholith.

Table 9.1 Summary of characteristic features of granite hosted and peribatholithic mineral occurrences for the South Mountain Batholith

| Deposit Type    | Elements                                                                                      | Host Rocks                                                                                                                                                                 | Alteration                                                                                                                                                           | Structures, Orientation                                                                                                                                                                                                                      | Comments                                                                                                                                                                                                                        |
|-----------------|-----------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Greisen         | Sr, W, Mo, As, Cu, Pb, Zn, F, Au, Ag                                                          | granodiorite, biotite ± muscovite monzogranite, leucomonzogranite, leucogranite                                                                                            | granitization (quartz, muscovite, biotite/muscovite), chloritization, K-feldspathization                                                                             | NW-trending quartz greisen veins                                                                                                                                                                                                             | largest deposits at pluton margins at shallow-dipping contact(s) and are hosted by "specialized" leucomonzogranite or leucogranite. Good economic potential.                                                                    |
| Vein            | U, Cu, Mn, P, F, Ag                                                                           | granodiorite, biotite ± muscovite monzogranite, leucomonzogranite, leucogranite                                                                                            | humatization, decalcification, silicification, clay alteration                                                                                                       | NE-trending shear/fracture zones                                                                                                                                                                                                             | largest deposits occur in interior portions of Stage 1 Plutons of the SMB and are hosted by granodiorite and biotite monzogranite. Good economic potential.                                                                     |
| Breccia         | Pb, Zn, Cu, Bi, Au, Ag, P                                                                     | leucomonzogranite                                                                                                                                                          | silicification, leucitization                                                                                                                                        | Little Tobacco Lake prospect is along part of the NE-trending TKZ. Dunderberg deposit is fault bounded dilation zone                                                                                                                         | mineralized zones show multiple superimposed episodes of silicification and brecciation, quartz textures typical of epizonal deposits. Potential for base- and precious-metal deposits.                                         |
| Pegmatite       | New Rose: Mo, Sn, W, Cu, Nb, Ta ± Be ± Li<br>Southwest Maguma Zone: Be, Li ± Sn ± W ± Ta ± Nb | New Rose: fine and coarse-grained leucomonzogranite<br>Southwest Maguma Zone: tonalite, granodiorite, monzogranite, leucomonzogranite, metamafic and metasedimentary rocks | minor greisenization, absent in most                                                                                                                                 | New Rose: randomly oriented pods, lenses and dykes<br>SW Maguma Zone: some sub-horizontal sheeted dykes                                                                                                                                      | Good potential for gemstones and possibly apatite in large dykes of SW Maguma Zone.<br>Low economic potential for small dykes near New Rose and east of SMB.                                                                    |
| Peribatholithic | Sr, W, U, Mo, Cu, Zn, Ag, Au                                                                  | metasedimentary and metaclastic rocks                                                                                                                                      | leucitization, chloritization and growth of opaque garnets (e.g. Duck Pond), silicification, sericitization and development of skarn (i.e. calc-silicate) mineralogy | mineralized zones consist of: variably oriented veins and dykes, stratabound zones in N or NE trending regional structures, variably oriented alteration zones<br>may be hosted by brecciated and leucitized host rocks (e.g. Skerrett Lake) | Located outside the periphery of the batholith, often associated with contact metamorphism in host rocks.<br>Some occurrences have associated apatite, fine grained leucopelite or pegmatite dykes.<br>Good economic potential. |

Mineral deposits in greisen occur throughout the batholith in both Stage I and Stage II plutons and are hosted by rocks ranging in composition from biotite granodiorite and mafic porphyry to muscovite-topaz leucogranite. Greisen-type occurrences are distributed throughout the entire batholith but the largest deposits and occurrences are either at, or proximal to, shallow-dipping contact zones between granite and metasediment, and to a lesser extent granite-granite contact zones. Some greisen-type deposits are spatially associated with major fault or shear zones, such as the East Kemptville tin deposit. However, at present it is not clear whether or not these structures have a genetic relationship with attending greisen mineralization; that is, whether structures served as loci for ore deposition. Many occurrences are restricted to, or have associated greisen-bordered quartz veins. These veins are predominantly oriented to the northwest (Fig. 9.3a), as noted by Horne *et al.* (1992).

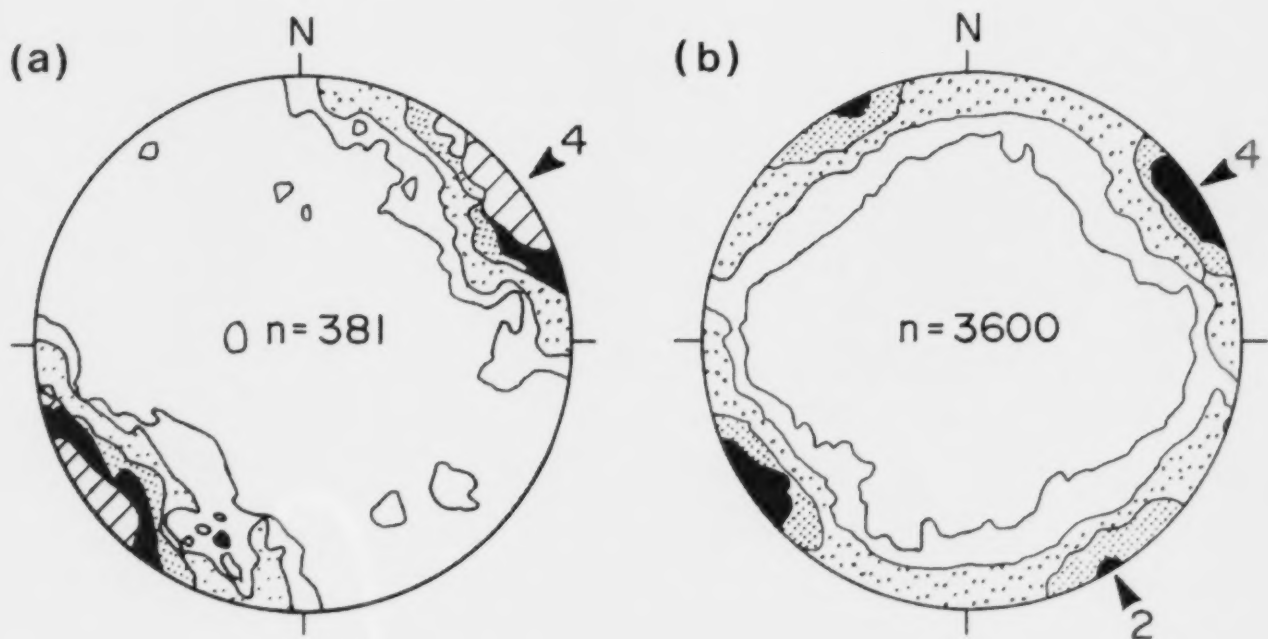


**Figure 9.3** Contoured density plots (after Horne *et al.*, 1988; 1992) of poles to: a) quartz veins (in 1% area;  $N=381$ ) from the entire batholith; and b) all joints in the eastern part of the SMB ( $N=3600$ ). Hematized joint, fracture and shear zones are mostly restricted to joint trend #2.

Greisen-type deposits occur as: (1) massive greisen zones generally ranging from 1-100 m in width and mostly occurring near contact zones. Some zones show development of

zonation (e.g. Inglisville; O'Reilly *et al.*, 1992); (2) northwest-trending, quartz-muscovite greisen-bordered quartz veins. Greisen borders range from <1 cm to approximately 1 m in width; and (3) sheeted quartz vein and quartz-muscovite greisen zones that are up to 500 m in length (e.g. Sandwich Point; MacDonald and O'Reilly, 1989). Characteristic ore minerals for greisen-type deposits include cassiterite, wolframite, scheelite, molybdenite, arsenopyrite, chalcopyrite, chalcocite, bornite, malachite, sphalerite, galena, fluorite and pyrite. A wide range of alteration mineral assemblages is associated with these deposit, including combinations of quartz, albite, K-feldspar, muscovite (phengite), topaz, tourmaline, fluorite and garnet.

Greisen-type mineral deposits may be dominated by quartz-topaz, quartz-muscovite, quartz-tourmaline or quartz-muscovite-tourmaline-topaz mineral assemblages, presumably reflecting the dominance of Si-F, Si-K, Si-B and Si-K-B-F elemental assemblages in the hydrothermal fluids that formed the greisens. The following are descriptions of significant greisen deposits that characterize three of these elemental assemblages.

#### Quartz-Topaz Greisen - East Kemptville Deposit (Sn-Zn-Cu-Ag)

The East Kemptville Sn-Zn-Cu-Ag deposit (Fig. 9.1) is a greisen-type deposit hosted by the muscovite-topaz-bearing East Kemptville leucogranite (Kontak, 1988) along the southwestern margin of the Stage II Davis Lake Pluton (Ham and MacDonald, 1991). As noted above, the deposit was discovered using geochemical and drift prospecting techniques by Shell Canada Resources in 1978 (McAuslan *et al.*, 1980). Subsequent diamond- drilling delineated a deposit consisting of an estimated 56,000,000 tonnes of 0.165 % Sn (Richardson, 1984; Moyle, 1985). Open pit production of ore began in 1985 and continued until January 1992 when mine operations ceased. Estimated reserves as of January 1991 were 15,200,000 tonnes of 0.206 % Sn (O'Reilly *et al.*, 1992). The East Kemptville deposit is arguably the most significant deposit in the South Mountain Batholith that has been discovered to date.

The deposit consists of two separate ore zones: the 'main zone' which forms an elongate embayment of leucogranite and associated greisens and the 'baby zone' consisting of greisenized leucogranite (Fig. 9.4a). Kontak (1990) concluded that the muscovite-topaz leucogranite that hosts the deposit was intruded into the metasedimentary rocks of the Meguma Group and later overprinted by mineralized greisens. Ore grade enrichment (>0.165 % Sn) is present in the



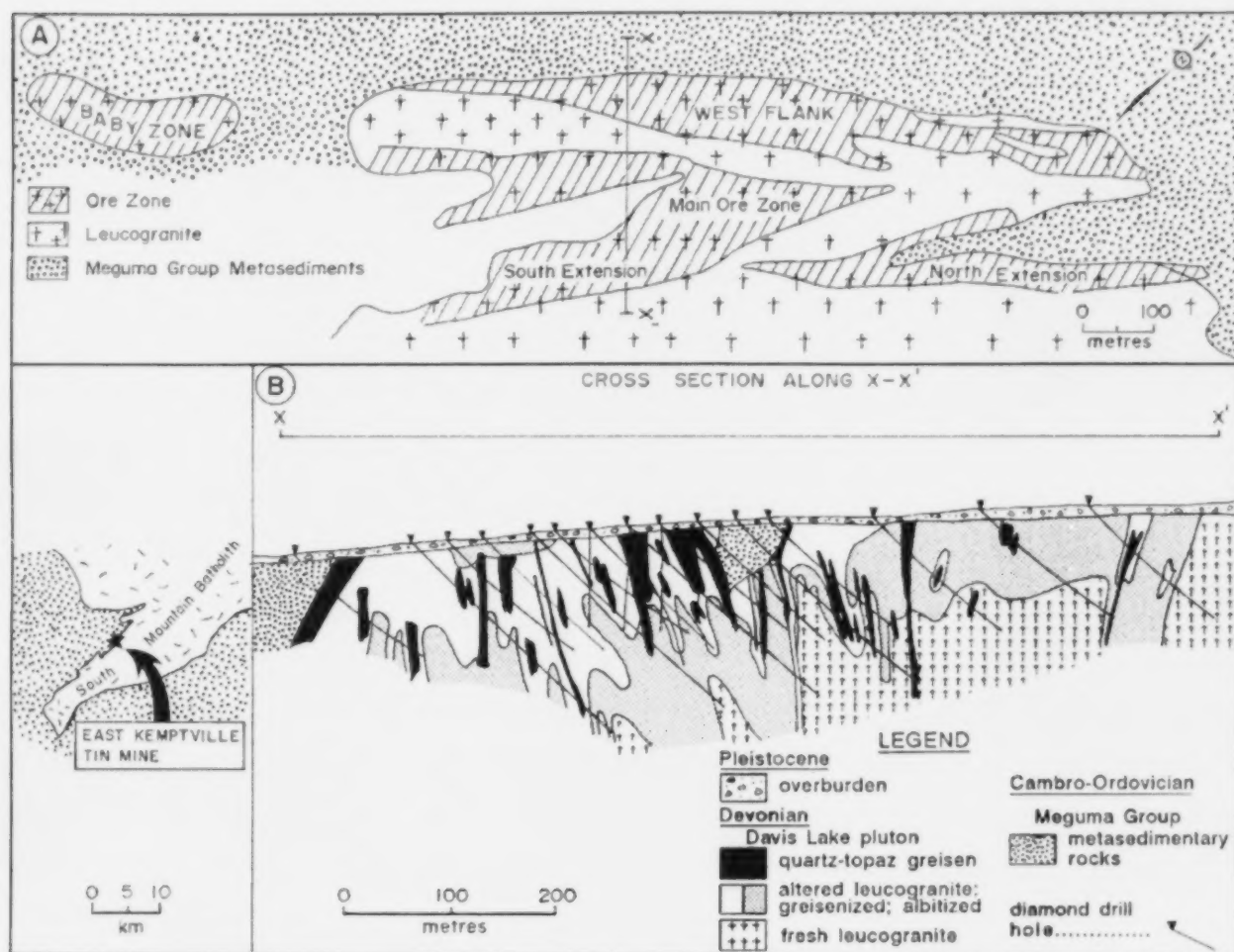


**Figure 9.4** Plan map (A) and cross-section of the East Kemptville Sn-Zn-Cu-Ag deposit showing the location of the main and baby ore zones (after O'Reilly *et al.*, 1992). Note the ore zones are proximal to the granite/metasediment contacts as shown in the plan map. Also note the close spatial association of quartz-topaz greisens to greisenized and albitized muscovite-topaz leucogranite.

upper 200 m of the 'baby zone' and ranges from absent to 200 m depth in the main zone (O'Reilly *et al.*, 1992). The ore zones in the main zone are directly adjacent to, and beneath, a shallow-dipping contact with metagreywacke of the Goldenville Formation, as shown in Figure 9.4b (Richardson, 1988; Kontak, 1990; O'Reilly *et al.*, 1992).

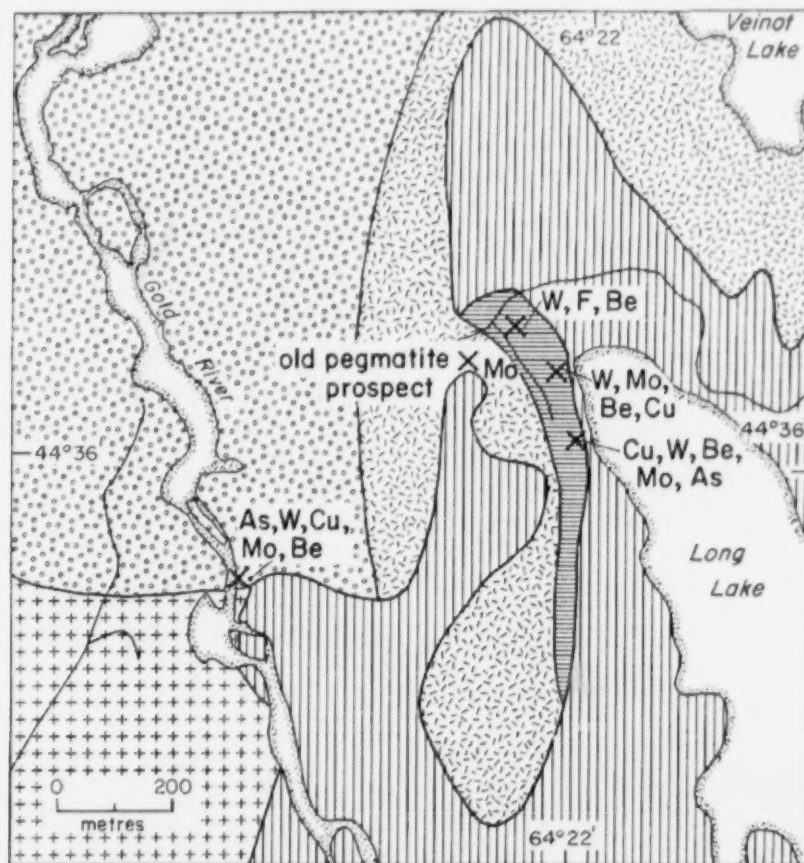
Minerals occur in two styles: (1) disseminated cassiterite, chalcopyrite, bornite, sphalerite and pyrite in dark grey to black quartz-topaz greisen. These greisen zones are mostly bordered

by greisenized leucogranite, which in turn is bounded by zones of albitized leucogranite; and (2) zoned greisen veins with cores of massive cassiterite bordered by inner zones of quartz-topaz  $\pm$  muscovite greisen and outer zones of quartz-muscovite greisen grading into unaltered muscovite-topaz leucogranite (Richardson, 1984; Kontak, 1990; O'Reilly *et al.*, 1992). Most of the ore along contact zones consists of the first type of greisen and surrounding greisenized or albitized leucogranite, as depicted in Figure 9.4b, whereas the second type of greisen occurs throughout the pit areas. Richardson (1984) reported a complex series of later or cross-cutting quartz  $\pm$  sulphide  $\pm$  phosphate  $\pm$  fluorite  $\pm$  beryl  $\pm$  carbonate  $\pm$  zeolite veins. She reported an extensive list of ore and gangue minerals, with accompanying paragenetic sequence, that includes cassiterite, chalcopyrite, sphalerite, pyrite, pyrrhotite, arsenopyrite, wolframite, molybdenite, galena, topaz, fluorite, quartz, muscovite, stannite, fluorapatite, triplite, illite, siderite, dolomite, marcasite, dickite, stilbite, childrenite, vivianite, rhodochrosite, rozenite, covellite, native copper, kellyite, beryl and columbite.

Several models have been proposed for the origin of the East Kemptville deposit and its leucogranite-leucomonzogranite host rocks. Richardson *et al.* (1982) and Chatterjee and Strong (1984, 1985) concluded that the East Kemptville greisens and associated greisenized leucomonzogranite were produced by alteration of a coarse-grained megacrystic phase of the circa 370 Ma South Mountain Batholith. In light of Rb-Sr geochronological data Richardson (1988) concluded that the deposit and indeed the entire Davis Lake Pluton was intruded and crystallized circa 330 Ma, approximately 40 million years after the main intrusion of the South Mountain Batholith. Kontak (1990) concluded that the deposit was formed by hydrothermal alteration of a discrete body of muscovite-topaz leucogranite. Kontak *et al.* (1989), Kontak and Cormier (1991), and Kontak and Chatterjee (1992) concluded that the East Kemptville deposit and associated granitoid rocks of the Davis Lake Pluton were emplaced and crystallized circa 370 Ma and the 'younger' date acquired by various workers in this pluton represents later thermotectonic overprinting and resetting.

#### Quartz-Muscovite Greisen - Long Lake Prospect (Mo-W-Sn-Be-Cu-Zn-Ag)

The Long Lake Mo-W-Sn-Be-Cu-Zn-Ag prospect (Figs. 9.1 and 9.5) is a greisen-type deposit along a shallow-dipping granite-metasediment contact zone in the southern portion of the Stage II New Ross Pluton (O'Reilly *et al.*, 1982). The deposit was drilled during several stages



# LEGEND

## DEVONIAN

### South Mountain Batholith

-  Greisens: predominantly quartz-albite-muscovite greisen, pods and fractures of muscovite-quartz greisen
-  Fine-grained muscovite-biotite leucomonzogranite and associated leucogranite: porphyritic and equigranular
-  Coarse grained muscovite-biotite leucomonzogranite, megacrystic
-  Biotite monzogranite: coarse grained, megacrystic

## CAMBRO-ORDOVICIAN

### Meguma Group

-  Goldenville Formation: spotted hornfels, slate and minor quartzite

Geological boundary 

Mineral occurrence 

Figure 9.5 Geology map of the Long Lake Mo-W-Sn-Be-Zn-Cu prospect (after O'Reilly et al., 1982). Mineralized and barren greisens are mostly restricted to quartz-muscovite-albite greisen zone developed along the shallow-dipping granite/metasediment contact. Pegmatite-hosted Mo mineralization occurs mostly in a microclinized fine grained leucomonzogranite.

of exploration but no estimates of the reserves are available.

The greisens and associated minerals at Long Lake are hosted by fine-grained leucomonzogranite and associated leucogranite at the contact with greenish slate of the Green Bay Formation (Corey, 1988a). Quartz-muscovite greisen pods and infillings are locally developed along irregular fractures, in addition to the pervasive quartz-muscovite-albite greisen. Both greisen types are host to mineralized disseminations, vugs and fracture fillings consisting of chalcopyrite, pyrite, arsenopyrite, wolframite, scheelite, molybdenite and fluorite. These greisen zones have been traced for 230 m along the granite metasediment contact and mainly range in width from 50-100 m (O'Reilly *et al.*, 1982).

Adjacent to the intensely greisenized zone is a larger band of microclinized leucomonzogranite and associated leucogranite. Most rocks in this band contain the assemblage quartz-orthoclase-albite-muscovite which is gradational with the greisen assemblage described above. Minerals occur in quartz-microcline veins and pegmatites, with local bands and scattered blebs of molybdenite.

MacDonald *et al.* (1988) noted that the leucogranite associated with the Long Lake deposit is gradational with the host leucomonzogranite. They, and later Clarke *et al.* (1993), concluded, based on field, petrological and geochemical data, that the muscovite leucogranite was formed by hydrothermal alteration of fine-grained leucomonzogranite, possibly by fluids that also produced the Long Lake greisens and associated mineralization.

#### Quartz-Tourmaline Greisen - Inglisville Prospect (Mo-As-Bi-Au)

A series of complexly zoned greisens are developed at Inglisville along the margin of a body of fine-grained leucomonzogranite immediately adjacent to the contact with hornfelsed slate of the Halifax Formation (Figs. 9.1 and 9.6; MacDonald and Ham, 1989b; Cormier, 1989). The greisen assemblage consists of a pervasive quartz-muscovite greisen that contains trace to minor amounts of biotite, tourmaline, garnet, chloritoid, chlorite and apatite. Superimposed on this assemblage are numerous zoned greisens consisting of tourmaline-greisen cores and quartz-greisen rims. The tourmaline greisens contain minor amounts of quartz and muscovite and trace amounts of chlorite and scheelite, whereas the quartz-dominant greisens contain minor muscovite and trace garnet, chloritoid, chlorite, wolframite and arsenopyrite. Small zones of greisen consisting of >95% muscovite occur in several of the greisen exposures. No detailed petrographic information

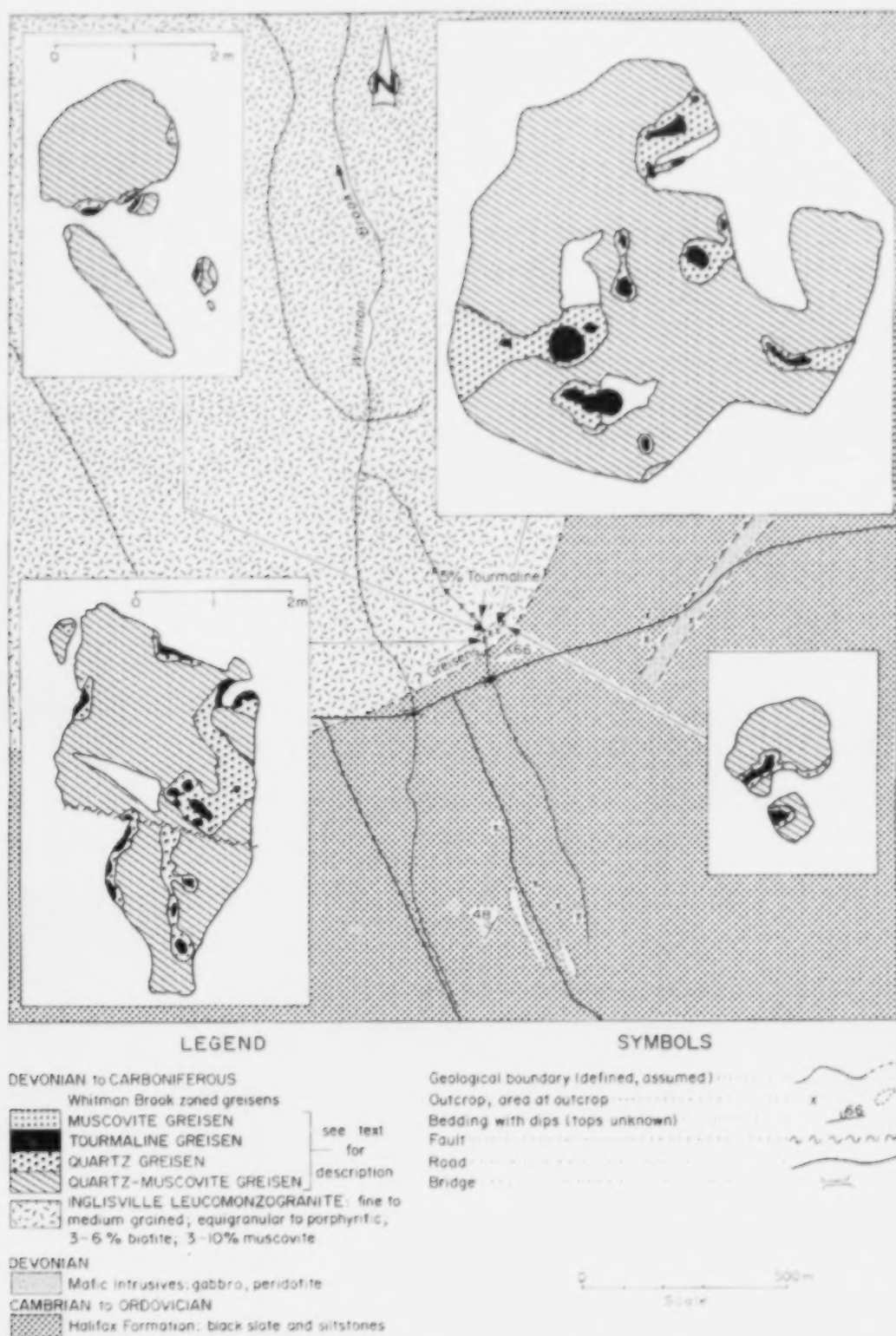


**Figure 9.6** Detailed geological map of the Inglisville zoned greisens (modified from Cormier, 1989). Note the zonal distribution of quartz-muscovite-, quartz- and tourmaline-dominated greisens with erratically distributed "pinch and swell" features. Several small ( $\leq 30$  cm) patches of muscovite-dominated greisen are randomly distributed throughout the area.



is available for this greisen type. The muscovite-dominant greisens do not form part of the zoned greisen assemblage and their distribution appears to be random with respect to other greisen types.

Virtually all of the feldspars have been obliterated in all four greisen types at Inglisville. The paucity of feldspars is reflected in the low concentrations of CaO, Na<sub>2</sub>O and K<sub>2</sub>O in the greisens compared with the host leucomonzogranite (O'Reilly *et al.*, 1992). The high levels of SiO<sub>2</sub> correspond to high modal percentages of quartz in the quartz-muscovite and quartz greisens. In general the greisens are depleted in P<sub>2</sub>O<sub>5</sub>, Ba, Rb and Sr and enriched in Ta, Nb, U, F, B, As, Au and W when compared with the host Inglisville leucomonzogranite. The erratic distribution of most major and trace elements in the greisen assemblage reflects the mineralogy of individual greisen types. For example, the highest B concentration is in the tourmaline greisen whereas the highest F and Li levels are in the muscovite-rich greisens.

The Inglisville greisens contain the first reported occurrence of chloritoid in a Meguma Zone granitoid body (Cormier, 1989). Chloritoid has also been reported in the sediment-hosted, exo-contact Duck Pond deposit (O'Reilly *et al.*, 1992). The Inglisville greisens also have the first reported occurrence of loellingite (FeAs<sub>2</sub>) in a granitic rock of the Meguma Zone. Trace amounts of loellingite were noted in a few samples of quartz-muscovite greisen. The presence of this sulphur-deficient mineral is interesting, particularly in light of the occurrence of trace amounts of sulphide minerals (e.g. molybdenite and arsenopyrite) within the same greisen system.

The Inglisville greisens are variably enriched in both Bi and Au with concentrations of up to 2400 ppm Bi and 690 ppb Au in samples of quartz-muscovite greisen. A Bi-bearing metallic mineral was detected by microprobe analysis. This mineral may be native bismuth or possibly a Bi-Au mineral phase similar to a mineral phase in the Big Indian Lake Pluton (M. C. Corey, personal communication) which would explain the high Au concentrations. MacDonald and O'Reilly (1989) noted significant gold enrichment in several greisen zones at, or near, granite-metasediment contacts throughout the South Mountain Batholith. They suggested that circulation of hydrothermal fluids through Au-bearing metasediments could be the source for the observed Au ( $\pm$ Bi) enrichment.

#### 9.3.2 Vein Deposits (U, Cu, Mn, P, F, Ag)

Vein deposits occur throughout the batholith (Fig. 9.1), in both Stage I and II plutons, and are hosted by rocks ranging in composition from biotite granodiorite to muscovite-topaz leucogranite. Unlike greisen-type deposits the largest vein deposits do not occur near contact zones but are in the interior of the batholith. Also the largest vein deposits, which include the Millet Brook U-Cu-Ag deposit and the former New Ross manganese mines (Fig. 9.7), are hosted by Stage I plutons, in contrast to greisen-type deposits primarily hosted by Stage II plutons. Vein-type deposits are invariably developed along northeast-trending fracture, fault or shear

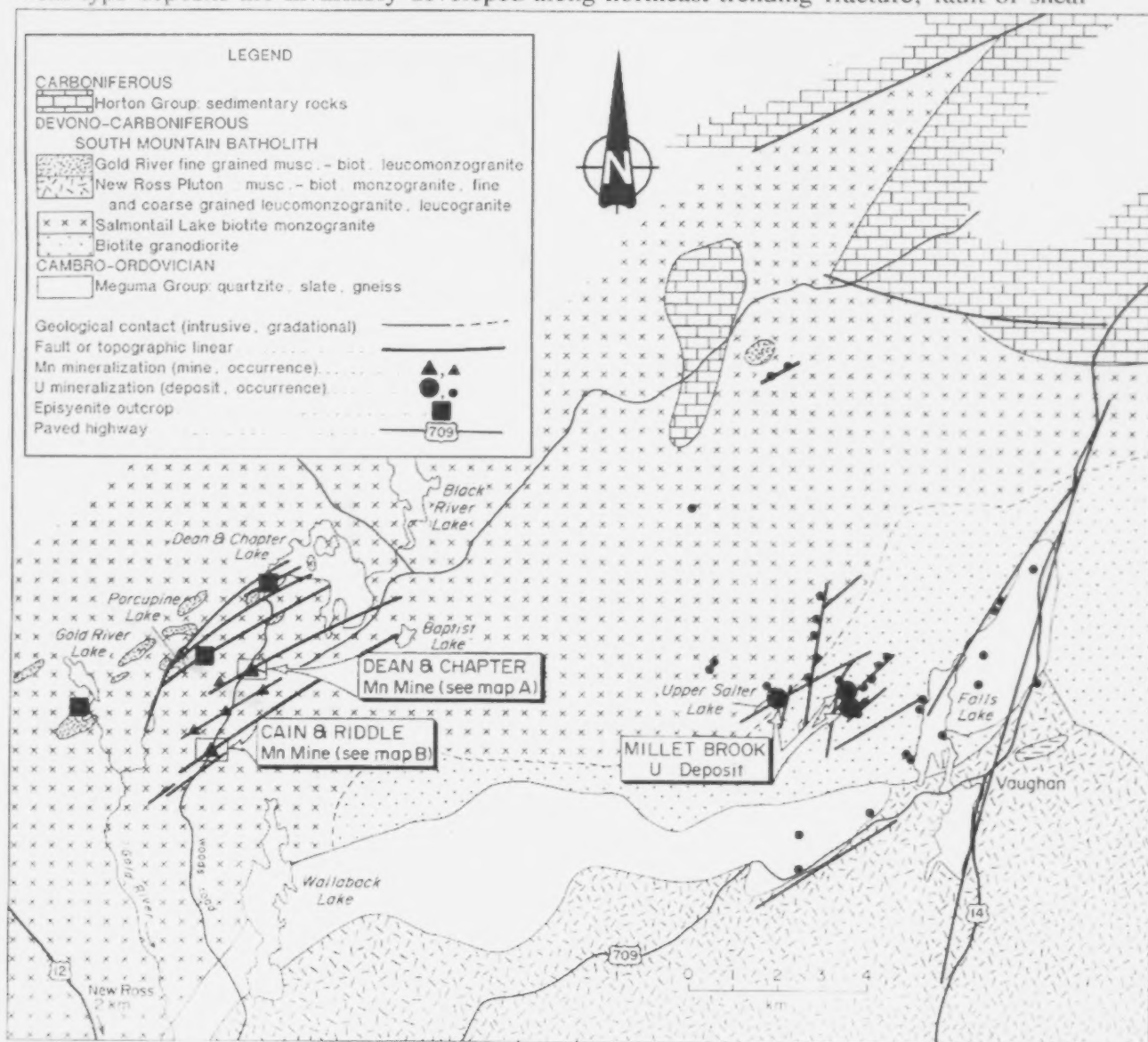


Figure 9.7 Geological map showing the location of the Millet Brook U-Cu-Ag Deposit and the New Ross Manganese (Mn-Fe) Mines (after O'Reilly et al., 1992).

zones, as noted by Horne *et al.* (1992; trend #2 in Fig. 9.3b). These zones are always intensely hematized and may display variable amounts of desilicification, albitization and clay alteration.

Vein-type mineral deposits may be dominated by  $U \pm Cu \pm Ag \pm P \pm F$  or  $Mn-Fe \pm P$  assemblages. The following are descriptions of the largest deposits that characterize these two vein-type metal associations.

#### Millet Brook Deposit (U-Cu-Ag)

The Millet Brook U-Cu-Ag deposit consists of mineralized veins in steeply-dipping, northeast-trending, en-echelon fracture zones (Fig. 9.8; Chatterjee *et al.*, 1985). The Millet Brook deposit is hosted by biotite granodiorite and Salmontail Lake biotite monzogranite and is situated approximately 2.5 km north and northwest of a metasedimentary inlier that extends from New Ross to Vaughan and forms the boundary between the Stage I Salmontail Pluton to the north and the Stage II New Ross Pluton to the south (Fig. 9.7). The en-echelon fracture-related nature of individual ore zones is graphically depicted in Figure 9.8. Veinlets and dykes of muscovite

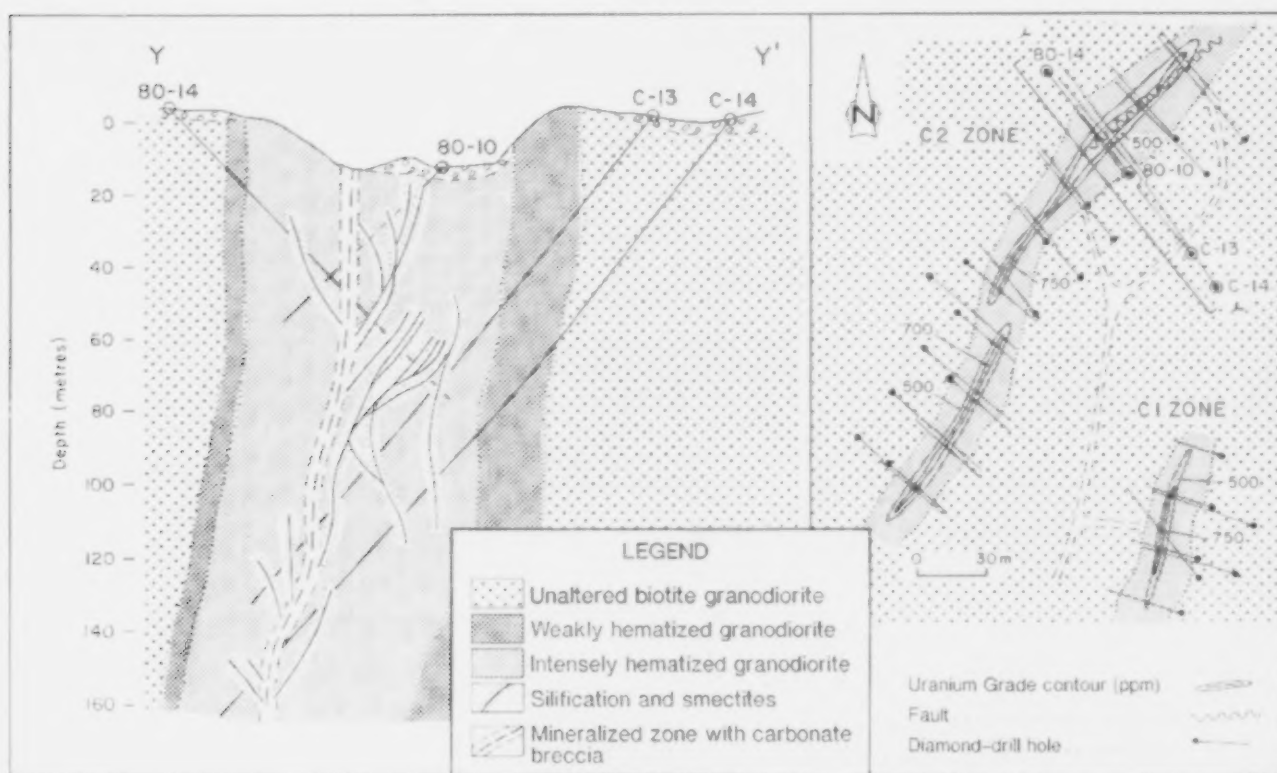


Figure 9.8 Plan map and cross-section from the Millet Brook U-Cu-Ag deposit showing the fracture-related nature and en-echelon distribution of individual ore zones (courtesy of G.A. O'Reilly).

leucogranite, texturally and mineralogically similar to the Lake Lewis leucogranite of the New

Ross Pluton, were noted in drill core from several mineralized zones in the northern part of the Millet Brook deposit area (Chatterjee *et al.*, 1985). The deposit has drill-estimated reserves of 1.0 million pounds  $U_3O_8$  with average grades of 0.15-0.20%  $U_3O_8$  over a 2.0 m width with a cut-off grade of 0.10%  $U_3O_8$  (Chatterjee *et al.*, 1982).

Pitchblende is the dominant uranium-bearing mineral in ore zones below 50 m depth, as outlined by drilling, whereas the U-phosphate minerals torbernite, autunite and Pb-meta-autunite are the dominant minerals above 50 m depth. This feature is as a result of surface weathering processes. Other ore minerals present in minor amounts at all depths include chalcopyrite, bornite, covellite, chalcocite, proustite, galena, sphalerite and wolframite. Gangue minerals include quartz, feldspars, micas, illite-smectite, andalusite, hematite, kaolinite, tourmaline, chlorite, calcite-ankerite, pyrite, Mn-oxides and anatase (Chatterjee *et al.*, 1982).

Alteration of the host biotite granodiorite is mainly confined to approximately 30 m from mineralized fractures and consists of albitization, muscovitization, biotitization, chloritization, K-feldspathization and carbonatization. Widespread hematization, consisting mainly of turbid or cloudy plagioclase and to a lesser extent K-feldspar, is partially as a result of the chloritization of biotite, a process that liberates Fe. Intense hematization and biotitization are closely associated with some ore zones (Corey, 1988b) and indicate the net introduction of Fe. Additionally, some ore zones have associated episyenite (desilicification) and/or silicified zones (Clarke and Chatterjee, 1988). The above alteration features are complexly inter-related in the Millet Brook deposit and there is no single characteristic alteration configuration surrounding mineralized veins.

#### New Ross Deposits (Mn-Fe-P)

As previously noted, the New Ross deposits, located approximately 10 km north of New Ross (Fig. 9.7), consist of two main centres, the former Cain and Riddle Mine and the former Dean and Chapter Mine. Manganese minerals occur in Mn-oxide veins and lenses along steeply-dipping, northeast-trending faults. Weeks (1946) estimated 41,000 tons of combined ore reserves from both mines. A full description of the geology, petrography and geochemistry has recently been published (O'Reilly, 1992), and the following description draws extensively from this work.

The manganese deposits are hosted by the Salmontail Lake biotite monzogranite of the

Stage I Salmontail Lake pluton. Several small ( $<1 \text{ km}^2$ ), elongate plugs of Gold River fine-grained leucomonzogranite outcrop near the deposits. These bodies are in both fault and intrusive contact with the biotite monzogranite and are interpreted as being localized along a pre-existing structural feature during emplacement (Ham, 1990; O'Reilly, 1992). A fine-grained body, interpreted as Gold River leucomonzogranite, was intersected in drill core at the former Dean and Chapter Mine (O'Reilly, 1992).

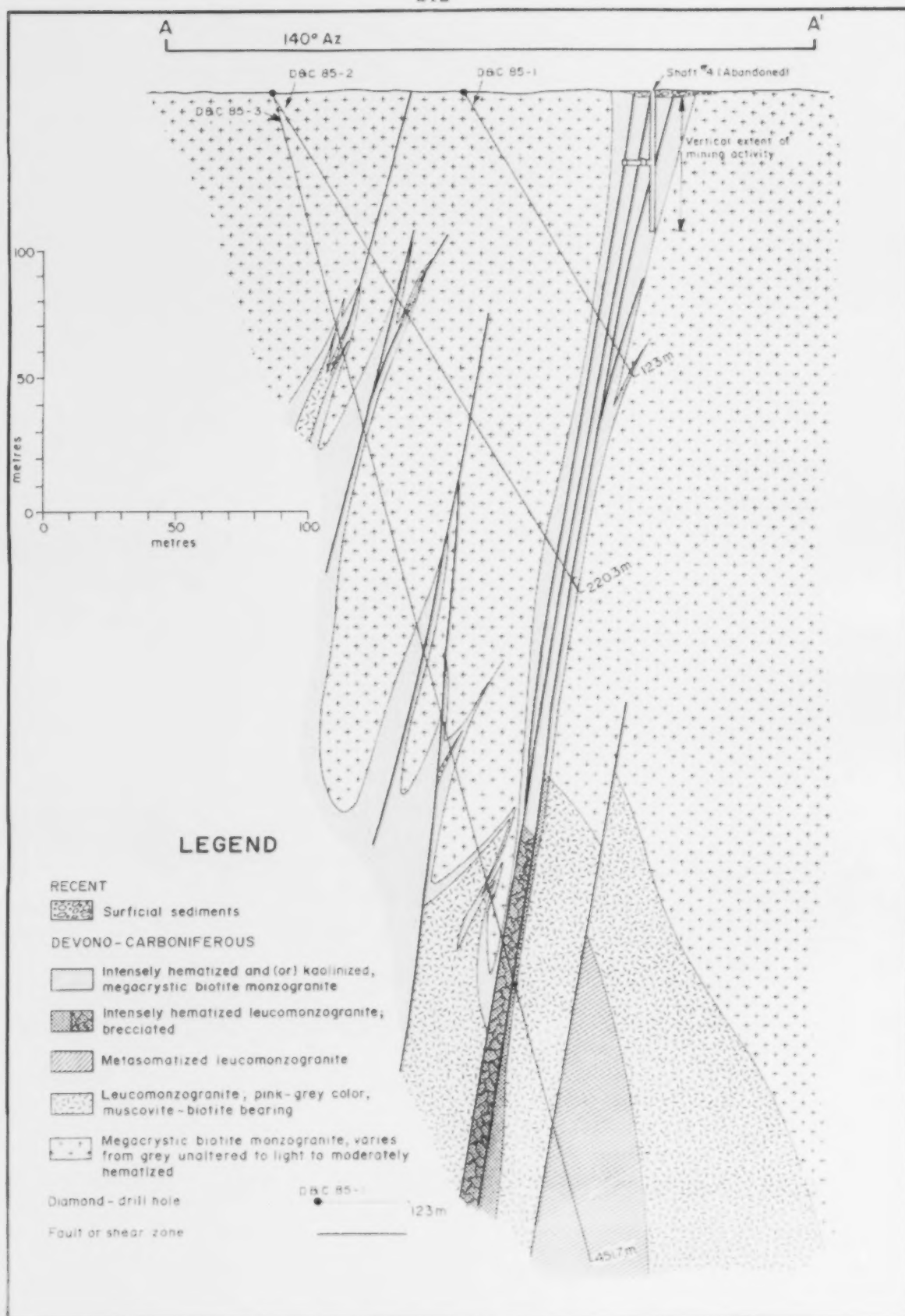
Pyrolusite and manganite are restricted to several northeast-trending, hydrothermally altered fault zones (Figs. 9.7 and 9.9). Mineralized veins pinch and swell both along strike and down dip, and range in width from a few centimetres to 1.8 m. O'Reilly (1992) noted that the Mn-oxides "occur as lensoid or chute-like masses in brick-red hematite-ochre breccia and hydrated Fe oxide". Enrichment in  $\text{P}_2\text{O}_5$  (up to 9.95 wt. %) in ore zones is reflected by the presence of fluorapatite.

The most pervasive alteration attending the Mn mineralization is hematization, which is reflected by a range in intensity from a slight reddening of plagioclase and chloritization of biotite to a brittle and friable, brick-red rock with completely obliterated feldspars and biotite. Carbonatization is closely associated with hematization and is manifest as disseminated and vein calcite, including black (Mn) and red (Fe) varieties. Some calcite is replaced by Mn-oxides indicating carbonatization preceded the main mineralization stage (O'Reilly, 1992). Argillic alteration, consisting of smectite (montmorillinite) replacement of plagioclase, is superimposed on hematite zones and extends into the biotite monzogranite.

Minor episyenite alteration, or desilicification, was noted in the Gold River leucomonzogranite and along some northeast-trending faults. This alteration, which consists of the destruction and removal of quartz, may impart a 'vuggy' porosity on the biotite monzogranite. Minor silicification and greisenization were noted within and adjacent to the Gold River leucomonzogranite and below the former Dean and Chapter Mine.

**Figure 9.9** (Following page) Geologic cross-section (A-A' from Fig. 9.8) through the Dean and Chapter Mine (modified after O'Reilly, 1992). Mn-Fe-P mineralization is hosted by northeast-trending hematized and variably brecciated alteration zones that cross-cut biotite monzogranite. Fine-grained leucomonzogranite similar to the small plugs ( $<1 \text{ km}^2$ ) of Gold River Leucomonzogranite that outcrop nearby, were intersected in a single drill hole (D & C 85-3).





O'Reilly (1992) noted that the Mn-Fe-P ore zones also had enrichments in Be (90 ppm), W (140 ppm), Mo (28 ppm), Pb (3000 ppm) and Cu (1400 ppm), compared with samples of unmineralized Salmontail Lake monzogranite.

### 9.3.3 Breccia Deposits (Pb, Zn, Ba, Au, Ag)

Breccia-type deposits are restricted to the trace of the northeast-trending Tobeatic fault zone (Giles, 1985) along, and near, the southern margin of the Stage II Davis Lake Pluton, near Little Tobeatic Lake (Figs. 9.1 and 9.10). Bedrock exposure in this portion of the batholith is very poor and much of the following geological interpretation is based on boulder and subcrop mapping. The contact between coarse-grained Davis Lake leucomonzogranite and the slate and metagreywacke of the Meguma Group is very irregular and is interpreted as representing an undulating roof-zone of the Davis Lake Pluton. This interpretation is supported by the presence of three large (5-15 km long) 'roof-pendants' of Meguma Group metasediments near the main granite-metasediment contact. A large leucomonzogranite body to the south of the batholith may actually be an extension of the Davis Lake Pluton. A small plug of fine-grained muscovite leucogranite is exposed to the north of the mineralized zone.

The Tobeatic Fault Zone has been traced for approximately 8 km and averages 100 m in width in the study area. These dimensions are primarily based upon the occurrence of milky-white quartz-breccia boulders and subcrop (Fig. 9.10; Corey and Horne, 1989b). Brittle and ductile deformation and silicification of wall rocks are visible for up to 500 m from the quartz-breccia zone.

Combinations of galena, sphalerite, barite, chalcopyrite, arsenopyrite and pyrite occur as fine and coarse disseminations in quartz-breccia boulders. Barite was also noted as "colloform crust infilling vugs and as large fan-shaped white crystal masses within vuggy quartz-breccia boulders" (Corey and Horne, 1989b). Associated alteration mainly includes silicification and kaolinization with minor hematization.

Analysis of mineralized boulders returned maximum assays of 4.9% combined Pb-Zn and 2% Ba (Dickie and Zwicker, 1983). Analysis of sulphide-rich breccia boulders revealed anomalous concentrations of gold with values ranging from 135-2035 ppb Au (Corey and Horne, 1989b). A compilation of company assessment reports (Corey and Horne, 1989b) indicated that heavy-mineral till separates from a large part of the Tobeatic Fault Zone near the southern

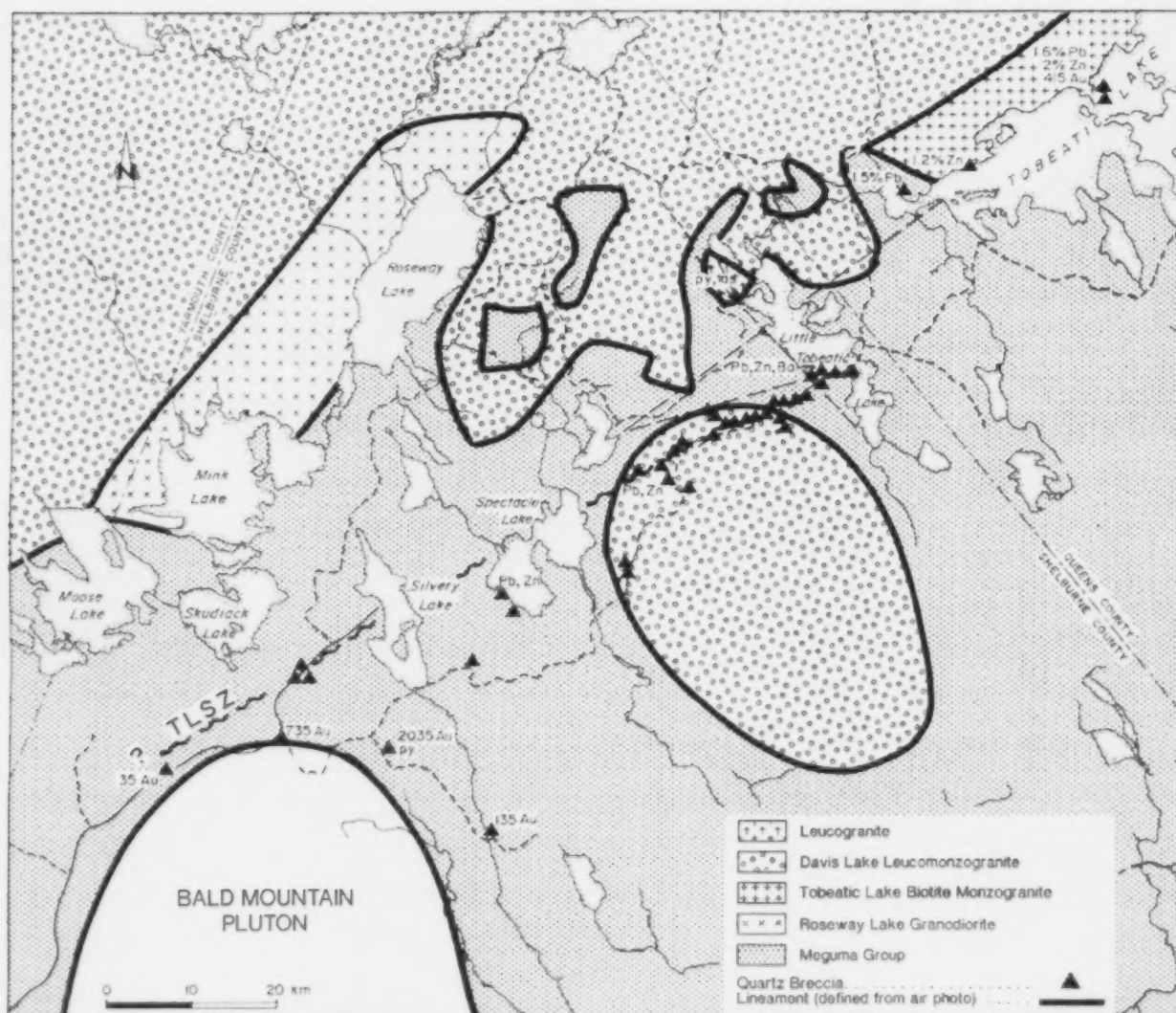


**Figure 9.10** Geological map of the Little Tobeatic Lake area showing the distribution of quartz-breccia boulders and outcrop (modified after Corey and Horne, 1989c). Mineral occurrences with sporadic assay data are also indicated where available.

margin of the Davis Lake Pluton contained anomalous concentrations of Zn, Pb, Sn, W and Au when compared to regional till samples (Fig. 9.11). This area is considered to be an excellent exploration target for base metals and precious metals.

#### 9.3.4 Pegmatite Deposits (Mo, Sn, W, Cu, Nb, Ta)

This group is only reported in the New Ross Pluton (east-central portion of batholith; Fig. 9.1) although it should be stated that unmineralized pegmatite dykes and pods are also

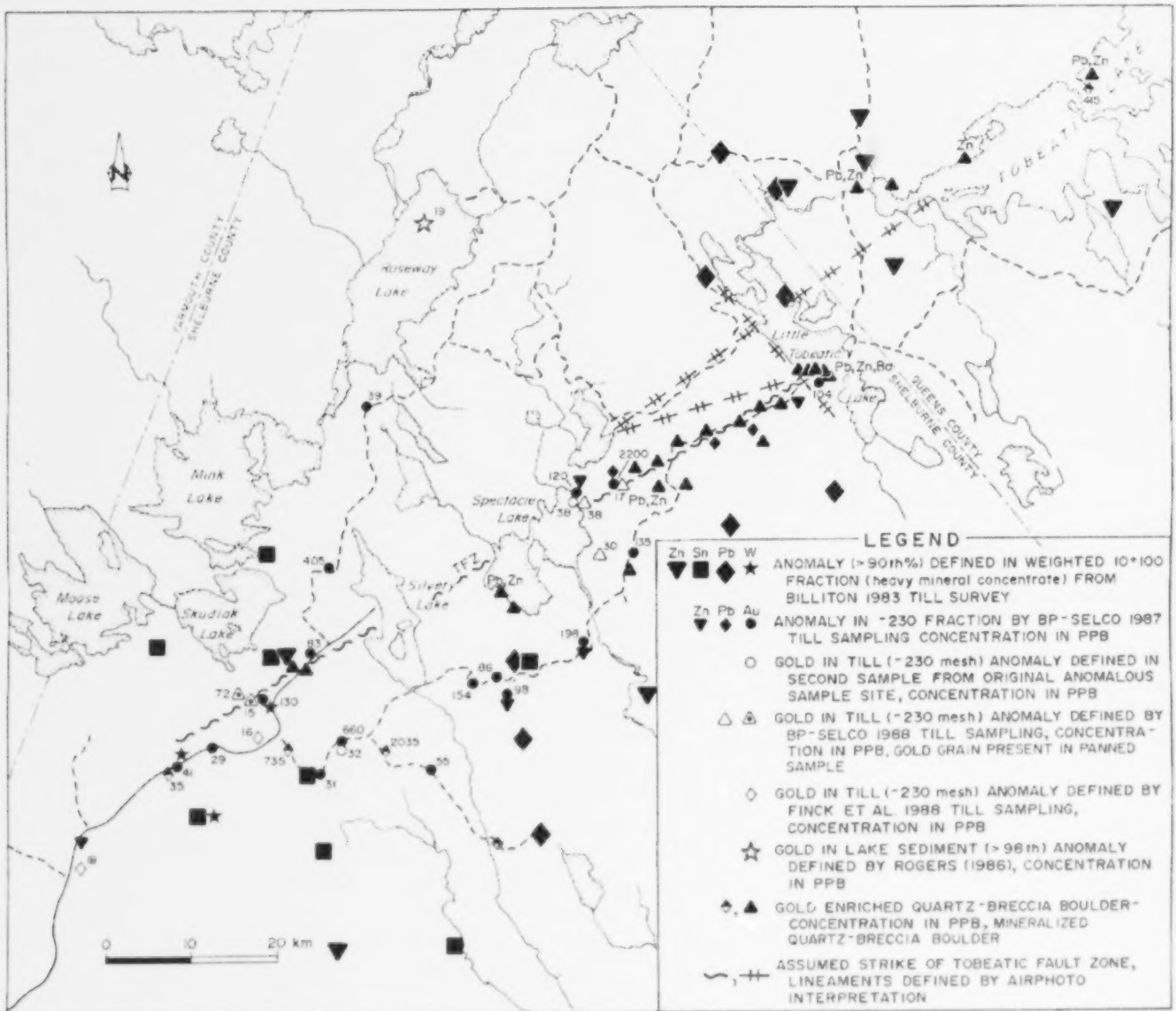


Figure 9.11 Compilation map showing the location of "anomalous": heavy mineral separates (-60 + 230 mesh) and silt and clay (-230 mesh) fractions from till samples; lake sediment samples; and mineralized boulders from the Little Tobeatic Lake area (after Corey and Horne, 1989c).

present in numerous other mineral deposits including the former East Kemptville Sn-Zn-Cu-Ag Mine (Kontak, 1990), the Gaspereau Lake U-P-F prospect (MacDonald and Ham, 1992) and Long Lake deposit (O'Reilly *et al.*, 1982). Pegmatite-type deposits are hosted only by fine- or coarse-grained leucomonzogranite and muscovite  $\pm$  topaz leucogranite. Individual pegmatite bodies are mostly  $\leq 10$  m in the maximum dimension. Mineralized zones occur in isolated



pods, lenses and dykes that, unlike the greisen- and vein-type deposits, have no preferred orientation.

In addition to the common minerals quartz, alkali feldspar, muscovite, biotite, garnet and cordierite, characteristic minerals in pegmatite include cassiterite, wolframite, scheelite, columbite, tantalite, tapiolite, beryl, fluorite, tourmaline, lepidolite, amblygonite and metatorbernite. Most mineralized pegmatites have quartz-muscovite greisenized borders and selvages, whereas others, including the Long Lake and Keddy occurrences (Fig. 9.1), are associated with extensive greisen zones (O'Reilly *et al.*, 1982).

The Keddy Mo-Ta-Nb prospect typifies pegmatite-type mineral deposits. The deposit consists of a series of pegmatite pods that intrude the Keddy-Reeves muscovite-topaz leucogranite. A few greisen and greisenized leucogranite zones are developed at the margins of some pegmatite pods. Pegmatite dykes and pods are only reported to contain molybdenite, whereas the occurrence of molybdenite, topaz, dumortierite, scheelite, andalusite, fluorite and columbite have been reported in the associated greisens (O'Reilly *et al.*, 1982).

#### 9.3.5 Peribatholithic Deposits (Sn, W, U, Cu, Zn, Ag)

These mineral occurrences are, by definition, located in the periphery of the batholith and are hosted by metasedimentary and/or metavolcanic rocks of the Cambro-Ordovician Meguma Group and the overlying Silurian to Devonian White Rock, Kentville and Torbrook formations. Most of the occurrences are located near the southwestern end of the batholith near the East Kemptville deposit, along the northwestern margin of the batholith near the Annapolis Valley and along the southern margin of the batholith near Caledonia.

Several of the deposits, including those at Caledonia (O'Reilly, 1985) and the Duck Pond deposit (Pitre and Richardson, 1989) approximately 2 km northwest of the East Kemptville deposit (Fig. 9.1), have associated Bouguer gravity anomalies that reflect the presence of less dense underlying granite bodies. Some deposits have fine-grained aplite, leucogranite or pegmatite dykes, such as those in the Caledonia area. Other deposits have small granite plugs, as at the Kempt Snare Lake prospect southwest of the East Kemptville deposit (Soehl, 1988; Soehl *et al.*, 1989) where a 'cupola' of black, graphite-bearing, greisenized leucogranite (approx. 200 x 500 m) is enriched in W, Sn, Pb, As, Cu and Ag. In the absence of outcropping granite dykes or plugs, a possible genetic link to the South Mountain Batholith or associated buried cupolas can



commonly be established on the basis of contact metamorphic mineral assemblages in metasedimentary host rocks. These minerals primarily include andalusite, commonly the chiastolite variety, and cordierite which are most readily observed in the pelitic sedimentary layers. Other evidence for the peribatholithic association with granitic rocks includes the development of skarnoid-type mineral assemblages and the granophile element assemblage with strong enrichments in Sn, W, F, Rb, Li or U, such as in the Caledonia occurrences (O'Reilly, 1985). Lastly, the styles of alteration superimposed on the host metasedimentary and metavolcanic rocks may be interpreted as resulting from granite-related fluids from associated intrusions, as at the Duck Pond deposit (Hattie, 1989; O'Reilly *et al.*, 1992) where intense hematization, chloritization and the growth of spessartite garnets in the host argillite are linked either to the East Kemptville deposit or an underlying granite cupola.

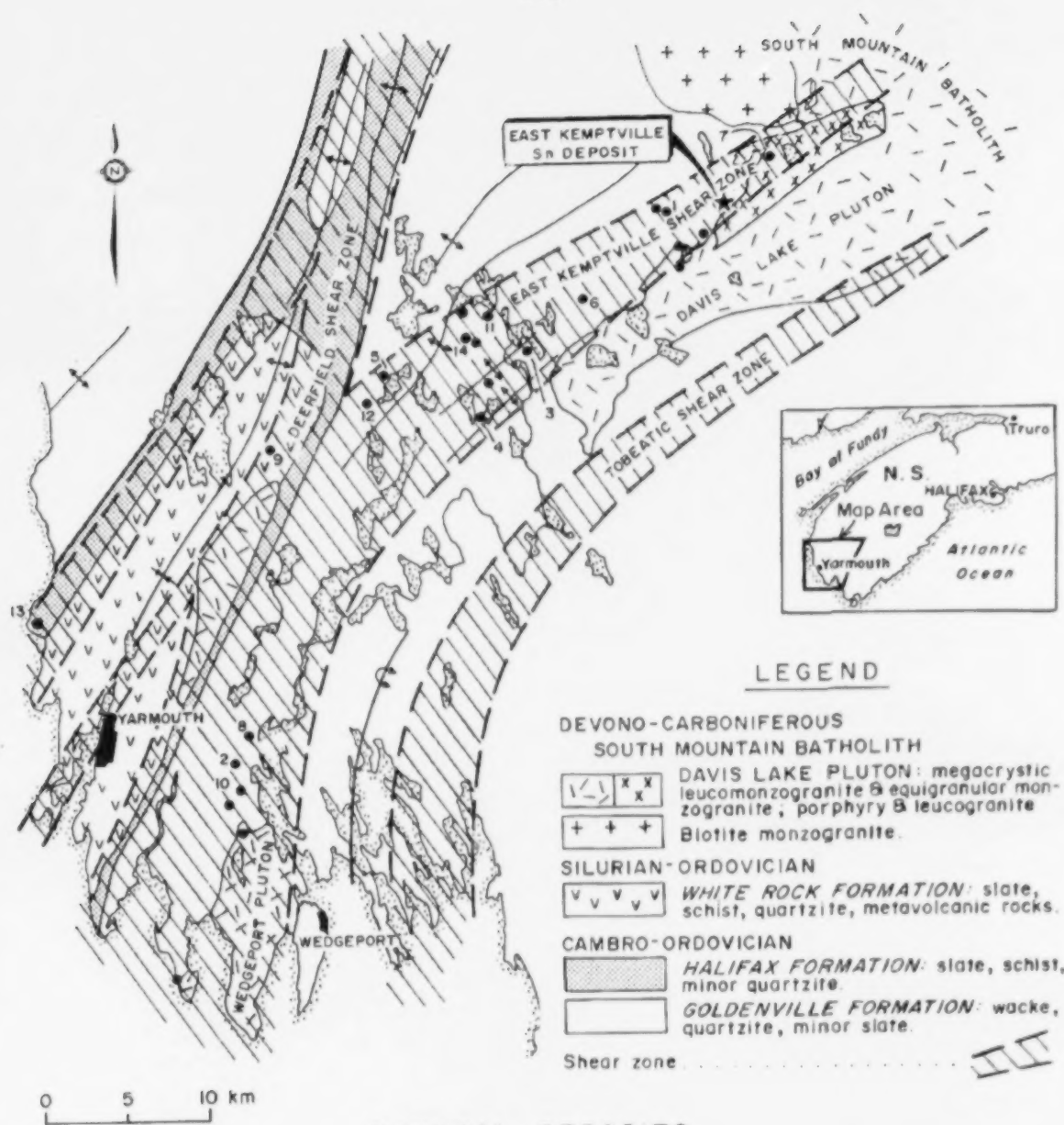
The following section briefly describes the three main areas near the batholith where peribatholithic deposits have been noted.

#### Southwest Nova Scotia Tin Domain

The Southwest Nova Scotia Tin Domain (Figs. 9.1 and 9.12) was first described by Chatterjee (1983) and Chatterjee and Strong (1984b) and was later studied by Kontak *et al.* (1990) and O'Reilly *et al.* (1992). It forms a northeast-trending band (approximately 20 x 70 km) that extends from a few kilometres northeast of the East Kemptville deposit to the Atlantic coastline near Yarmouth and Wedgeport. It is host to numerous polymetallic tin, base- and precious-metal, granite-hosted and metasediment-hosted (i.e. peribatholithic) deposits. A description of the geology and metallogenic significance of the tin domain is given in Kontak *et al.* (1990).

The largest peribatholithic deposit in the tin domain is the Duck Pond deposit (Fig. 9.12) with drill-indicated reserves of 5.1 million tonnes of 0.129% Sn (O'Reilly, 1988). The deposit has been studied by Pitre and Richardson (1989), Hattie (1989) and O'Reilly (1988). Details about exploration activity have also been reported in various assessment reports from Shell Canada Resources and Rio Algom (O'Reilly *et al.*, 1992). Kontak *et al.* (1990) summarized the geology of the deposit and the following description draws liberally from their work.

Mineral deposits occur as three main types including: (1) stratabound cassiterite in altered



★ East Kemptville Sn-Cu-Zn-Ag deposit

●<sup>2</sup> (number refers to list below)

● no name recorded

1. Duck Pond Sn-Zn deposit
2. Dominique Sn-Zn-Cu-Pb deposit
3. Pearl Lake Sn-Cu-Sn prospect
4. Kempt Shore Lake W-Pb-Zn-Ag prospect
5. Fanning Lake Cu-Pb-Zn-Sb-Ag prospect
6. Gardners Meadow Brook Sn prospect
7. Dog Lake Sn-Cu prospect

8. Egypt Road Sn-Cu-Pb-Zn prospect
9. Brazil Lake Li pegmatite
10. Lower Plymouth Lake Sn-Cu-Pb-Zn-Ag prospect
11. Kemptville Au mine
12. Carleton Au mine
13. Cranberry Point Au mine
14. Kempt Back Lake Au-Sb prospect

Figure 9.12 Geological map of southwest Nova Scotia tin domain showing the location of the peribatholithic mineral occurrences and deposits.

strata (chlorite, chloritoid, garnet); (2) quartz-chlorite-cassiterite-sulphide veins; and (3) pyrite $\pm$ cassiterite $\pm$ base metal sulphides in silicified and sericitized zones. All types show subsequent hematization (Kontak *et al.*, 1990). The Duck Pond deposit is hosted by the transition zone between the Goldenville and Halifax formations of the Meguma Group which shows a northeast-trending penetrative fabric that has been locally overprinted by a similar-trending shear fabric. Three mineralized zones occur subparallel to bedding contacts at the Duck Pond deposit (Hattie, 1989; O'Reilly, 1987).

Other Sn-bearing peribatholithic occurrences in the tin domain include those at Kempt Snare Lake (Pb-Zn-W-Cu-Ag), Dominique (Sn-Zn) and Pearl Lake (Sn-Cu-Zn; Fig. 9.12). The geology of these occurrences is summarized in Kontak *et al.* (1990). The Kempt Snare Lake deposit (Soehl, 1988; Soehl *et al.*, 1989; Kontak *et al.*, 1990) consists of (in descending order of abundance) arsenopyrite, sphalerite, galena, scheelite, and chalcopyrite in quartz veins and greisens. Diamond-drilling at the Kempt Snare Lake deposit revealed the presence of an underlying graphite-bearing greisenized leucogranite cupola (Jensen, 1987; Soehl, 1988). Kontak *et al.* (1990) noted that the greisens at this deposit bore striking resemblance to the dark-coloured greisens at the East Kemptville deposit.

The Dominique deposit (Chatterjee *et al.*, 1985; Wolfson, 1983; Kontak *et al.*, 1990) consists of cassiterite, sphalerite, pyrite, pyrrhotite, galena, arsenopyrite and chalcopyrite in extensively chloritized zones in metagreywacke of the Goldenville Formation. Mineralized zones are restricted to three en-echelon east-northeast-trending fault zones with maximum grades of 0.72% Sn and 2% Zn over 4.14 m apparent width (O'Reilly *et al.*, 1992). Kontak *et al.* (1990) suggested that the Wedgeport Pluton extends to the north, beneath the metasedimentary rocks of the Meguma Group, and that the Dominique deposit represents the effects of granite-derived fluids from this body that migrated upward along structural features.

In summary, most peribatholithic mineral occurrences within the Southwest Nova Scotia Tin Domain are interpreted to represent exo-contact mineralization, either from extensions of the Davis Lake, Scrag Lake or Wedgeport Plutons, or from discrete buried cupolas. This observation is in accord with the work of Kontak *et al.* (1990) who postulated that sediment-hosted mineralization in the tin domain is a surficial manifestation of buried granite cupolas, possibly

similar in composition to the topaz-bearing East Kemptville leucogranite.

#### Annapolis Valley U-Ag-Cu Domain

The Annapolis Valley U-Cu-Ag Domain was first outlined by Chatterjee (1983). It extends along the north-central margin of the batholith from near Weymouth to Aylesford Lake and contains both endo- and exo-contact mineral occurrences. Two main areas of peribatholithic mineral occurrences are the Shortliff Lake (MacDonald and Ham, 1989a) and Randall Lake (MacDonald and Ham, 1992) areas (Fig. 9.1). The uranium occurrence at Randall Lake consists of pitchblende and autunite in brecciated and hematized metasediments and granite at the contact between metasediments of the Halifax Formation and the Cloud Lake biotite monzogranite (MacDonald and Ham, 1992). Trenching by Shell Canada Resources (St. George, 1982) revealed that uranium was restricted to the roof zone of the batholith. A pitchblende-bearing boulder from this area returned assay values of 5%  $U_3O_8$ . Analysis of drill core from Randall Lake indicated levels of up to 0.85% Cu and 0.12 oz./ton Ag over 1.0 m (St. George, 1982).

The Shortliff Lake (U-Cu-Ag) occurrence consists of veined, brecciated and hematized metasediments containing pitchblende, pyrite, covellite, chalcocite, chalcopyrite, bornite, native copper and specular hematite (Dakers, 1982). This occurrence is hosted by calcareous metasediments of undivided White Rock and Kentville formations (MacDonald and Ham, 1989a). O'Reilly *et al.* (1992) noted that several peribatholithic occurrences in the Annapolis Valley polymetallic domain have "... anomalous, but sporadic, levels of Bi-Cu-Ag-Co-Zn". They concluded that the anomalous concentrations of Bi and Co in these deposits set them apart from F-,  $CO_2$ - and P-rich vein-type occurrences of the central and eastern batholith (e.g. Millet Brook, Gaspereau Lake).

#### Caledonia (Sn, W, base-metal)

The Westfield - Caledonia area is situated along the south-central margin of the batholith (Fig. 9.1). This area is host to W-Sn-Mo-Ag endo-contact mineral occurrences (Westfield) in a greisenized leucomonzogranite protuberance of the Little Round Lake Pluton, and Sn-W-Mo-base metal-precious metal exo-contact mineral occurrences (Caledonia and Westfield) in a series of quartz fissure veins and associated greisenized zones (O'Reilly, 1985). The following section

focusses on the occurrences near Caledonia.

Regional exploration near Caledonia by Shell Canada Resources Ltd. (Wilson, 1978) resulted in the discovery of Sn-W mineralized boulders and outcrops. Subsequent follow-up work by Shell Canada Resources Ltd. and Billiton Canada Ltd. in the late 1970s and early 1980s included geochemical and ground gravity surveys (MacGillivray, 1982; Dickie, 1983). This work indicated the presence of a buried granite cupola beneath a gravity low southeast of the village of Caledonia and was supported by the presence of two dyke-like bodies that intrude the Meguma Group metasediments. One dyke consisted of a narrow (< 2 m wide) quartz-albite-chlorite-pyrite porphyry dyke while the other consisted of a 200 m long composite dyke containing albitite, quartz-albite rhyolite porphyry, and an albite- and tourmaline-bearing breccia with angular metasedimentary clasts (i.e. xenoliths; O'Reilly, 1985).

Subsequent diamond-drilling of three holes (197 m depth @ 85° inclination and 236 m depth, vertical hole: MacGillivray, 1983; 681 m depth, vertical hole: O'Reilly, 1987) failed to intersect a buried granite body. However, several features encountered in the core supported the presence of a buried cupola. These include the increased size of porphyroblasts with increased depth in 'spotted slates' and the presence of mineralized skarn layers (Sn-W-Cu-Pb-Zn) which are typically developed in close proximity to igneous bodies (O'Reilly, 1987).

Mineralization in the Caledonia area is represented by greisen veins and associated breccia pipes containing cassiterite, scheelite and base metal sulphides (O'Reilly, 1987). In addition, coarse crystals of cassiterite and wolframite were noted along contacts between "bull quartz" veins and host metasedimentary rocks (MacGillivray, 1983).

#### 9.4 Discussion

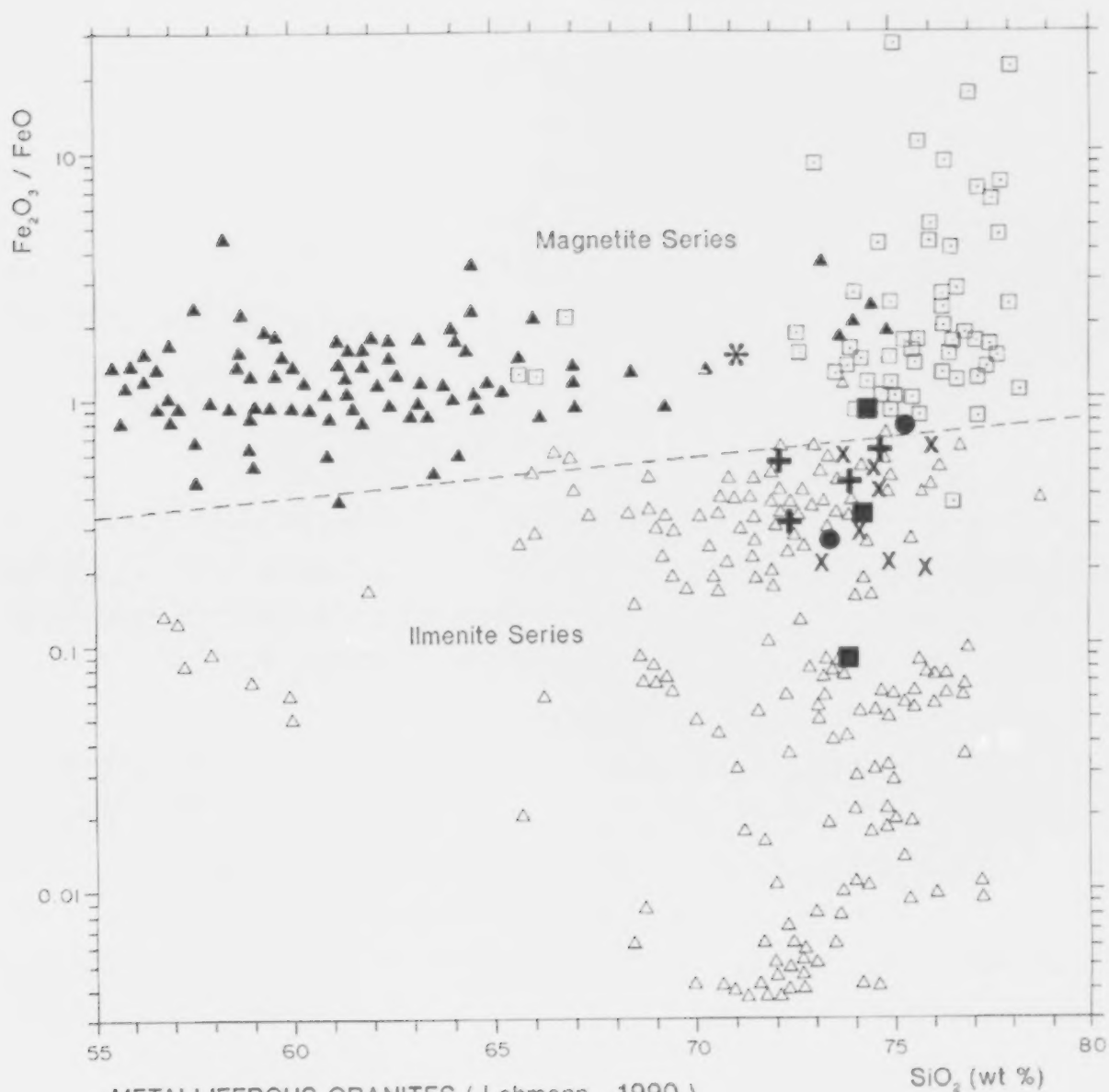
It is widely accepted that the type of granite-related mineralization is dependent upon the overall composition of the host granitoid intrusions (e.g., Strong, 1988; Lehmann, 1992; and references therein). Detailed petrographic studies indicate that all of the rocks of the various plutons of the South Mountain Batholith have similar mineralogical characteristics. The presence of low Mg/Fe biotite, muscovite, andalusite, cordierite ( $\leq 5\%$ ), garnet, tourmaline and ilmenite, combined with the absence of hornblende and rare occurrence of titanite, is consistent with the characteristic mineral assemblages for peraluminous, S-type and ilmenite-series granitoid rocks.



Additionally, detailed chemical studies demonstrate that all rocks of the batholith are peraluminous (i.e., molecular proportions  $\text{Al}_2\text{O}_3/(\text{CaO}+\text{Na}_2\text{O}+\text{K}_2\text{O}) < 1$ ) and have similar overall chemical characteristics with high levels of  $\text{SiO}_2$  ranging from average values of 67.12 (Std. Dev. 1.73) in biotite granodiorite to 73.62% (Std. Dev. 0.89) in muscovite $\pm$ topaz leucogranite. Conversely the rocks of the batholith have low concentrations of CaO ranging from average values of 1.94% (Std. Dev. 1.73) in biotite granodiorite to 0.39% (Std. Dev. 0.14) in muscovite $\pm$ topaz leucogranite. These features are consistent with worldwide granitoid rocks that are mainly host to SWUM-type (i.e., Sn-W-U-Mo) mineral deposits (Strong, 1988). A plot of  $\text{Fe}_2\text{O}_3/\text{FeO}$  versus  $\text{SiO}_2$  for a select suite of samples (Fig. 9.13) indicates the batholith is similar in composition to other worldwide Sn-bearing, ilmenite-series granitoids.

From the previous descriptions, it is apparent that there is a close spatial association between 'specialized granites', consisting mainly of muscovite-topaz leucogranite and to a lesser extent fine-grained leucomonzogranite, and the mineral deposits of the South Mountain Batholith. These rocks collectively have very high levels of large ion lithophile and other 'incompatible' elements compared with the rest of the batholith. Specifically these rocks are enriched in Rb, Cs, Li, Nb, Ta, Sn, W, U and F and depleted in Sr, Eu, Ba, Ti and Fe compared with the rest of the batholith or "normal" granitoid rocks (MacDonald *et al.*, 1992b). This association between mineral deposits and specialized granites is consistent with other tin districts throughout the world (cf. Lehmann, 1990, and references therein). Many of the greisen- and pegmatite-type occurrences in the batholith are actually hosted by leucomonzogranite and leucogranite of Stage II plutons. The East Kemptville deposit, for example, is hosted by a muscovite-topaz leucogranite. Similarly the breccia-type mineral occurrences near Little Tobeatic Lake are proximal to several small plugs of fine-grained leucomonzogranite. Vein-type mineral occurrences are mainly hosted by non-specialized biotite monzogranite or biotite granodiorite in Stage I plutons. However, leucogranite dykes and/or plugs occur at, or in close proximity to, these occurrences. Examples include leucogranite dykes that were intersected in drill core at the Millet Brook deposit (Chatterjee *et al.*, 1985) and several leucomonzogranite

**Figure 9.13** (Following page)  $\text{SiO}_2$  versus  $\text{Fe}_2\text{O}_3/\text{FeO}$  variation diagram for granitic rocks in association with Cu, Mo and Sn deposits from various locations worldwide (modified after Lehmann, 1990). The ilmenite series/magnetite series dividing line (after Ishihara *et al.*, 1979) is for granitoid rocks from Japan. The asterisk is for a brecciated and hydrothermally altered albite-magnetite-bearing leucomonzogranite from the Davis Lake Pluton that was first noted by Richardson (1988), and is the only known magnetite-bearing sample in the batholith.



METALLIFEROUS GRANITES ( Lehmann, 1990 )

- |            |   |
|------------|---|
| Tin        | △ |
| Molybdenum | □ |
| Copper     | ▲ |

DAVIS LAKE PLUTON

- |                                  |   |
|----------------------------------|---|
| Muscovite-Topaz Leucogranite     | ■ |
| Fine Grained Leucomonzogranite   | ● |
| Coarse Grained Leucomonzogranite | × |
| Muscovite-Biotite Monzogranite   | + |
| Albite-Magnetite Breccia         | * |

plugs that occur along the trace of northeast-trending shear zones at the New Ross Mn deposits (O'Reilly, 1992).

Chatterjee and MacDonald (1991) established a genetic link between leucomonzogranite, leucogranite and hosted greisens (including those at the East Kemptville deposit) in the Davis Lake Pluton, using trace element and rare earth element geochemical and isotopic evidence. They noted the presence of two series of leucomonzogranite, leucogranite and greisen (arbitrarily termed A and B) with distinct geochemical and isotopic characteristics. Series A rocks are characterized by flat or slightly-fractionated REE patterns (Figure 9.14a) whereas series B rocks have much more fractionated heavy REE (i.e. Gd to Lu) patterns (Fig. 9.14b) and lower  $\Sigma$ REE values than the A series rocks. Chatterjee and MacDonald also noted a clear separation between the two rock series on a plot of  $^{206}\text{Pb}/^{204}\text{Pb}$  versus  $^{208}\text{Pb}/^{204}\text{Pb}$ . They noted that in spite of the two separate trends in the thorogenic ( $^{206}\text{Pb}/^{204}\text{Pb}$  versus  $^{208}\text{Pb}/^{204}\text{Pb}$ ) diagram there were linear variations in the  $^{208}\text{Pb}/^{204}\text{Pb}$  versus  $^{232}\text{Th}/^{204}\text{Pb}$  and  $^{238}\text{U}/^{204}\text{Pb}$  versus  $^{206}\text{Pb}/^{204}\text{Pb}$  diagrams which imply immobility of U, Th and Pb since the time of crystallization of leucomonzogranite and leucogranite and the overprinting greisenization. Two important observations can be made on the basis of REE and Pb isotopic data. Firstly these data reveal clear genetic relationships between the greisens mineralization and associated leucogranite in the Davis Lake Pluton. This is the best documentation of a genetic link between deposit and "specialized" granites that exists for the batholith.

Kontak (1994) established a similar genetic link between the leucogranite and greisens at the East Kemptville deposit and the leucomonzogranite of the Davis Lake Pluton. The implication of these studies is that a genetic link can be made between 'specialized granites' and mineralization in the Davis Lake Pluton.

As previously noted, an evaluation of published geochronological data (MacDonald et al., 1992) indicates that all thirteen plutons of the South Mountain Batholith were emplaced and crystallized within a very narrow time interval, say  $\leq 5$  Ma at ca. 370 Ma. The concordance of all the radiometric dating techniques (e.g. K/Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  on biotite and muscovite, Rb/Sr, Pb/Pb and U/Pb methods for whole-rock and mineral separates) which collectively have a large range in terms of blocking temperatures (i.e. near the granite solidus to ca. 250°C) implies rapid post-crystallization cooling. Younger dates within the batholith reflect variable degrees of

updating during subsequent thermal and tectonic disturbances. Several studies of the mineral deposits and occurrences indicate a narrow time interval between crystallization and mineralization. Chatterjee and MacDonald (1991) conducted a Pb-Pb study of leucomonzogranite, leucogranite and attending mineralized greisens from the Davis Lake Pluton. They noted a remarkable co-linearity in the  $^{206}\text{Pb}/^{204}\text{Pb}$  versus  $^{207}\text{Pb}/^{204}\text{Pb}$  diagram for the entire sample suite which represented an age of  $365.7 \pm 2.7$  Ma (MSWD 1.95, 2 sigma). They concluded that the mineralized greisens formed contemporaneously with the crystallization of the Davis Lake Pluton. Kontak and Chatterjee (1992) measured the Pb-Pb isotopic concentrations for a suite of leucogranite and mineralized greisens from the East Kemptville Sn deposit. They concluded that the deposit formed ca. 366 Ma, shortly after the crystallization of the host leucogranite. Kelpie et al. (1993) measured an age for muscovite from the Millet Brook U deposit by the  $^{40}\text{Ar}/^{39}\text{Ar}$  technique. They noted an age of  $369.9 \pm 6$  Ma for the deposit which was very similar to ages for nearby biotite monzogranite ( $366.1 \pm 5$ ) and leucomonzogranite ( $373.1 \pm 6$ ) indicating the deposit was essentially contemporaneous with the nearby Stage I and II plutons.

Several studies have indicated that structure played a role in mineral deposition in the batholith. Horne *et al.* (1992) presented a detailed synthesis of structural data for the batholith, including data for planar features including joints, dykes (i.e. aplite, pegmatite), quartz veins (mineralized and barren) and fracture or shear zones and faults (Fig. 9.3a,b). These authors and MacDonald *et al.* (1992b) concluded that these planar features developed during northwest, horizontal compression accompanying uplift during the waning stages of the Acadian orogenic event. These workers noted the strong structural control on northeast-trending uraniferous and barren hematized shear zones and northwest-trending polymetallic and barren quartz veins throughout the batholith. These observations are consistent with features at several deposits, including the former New Ross manganese mines. Kontak (1990) and Halter *et al.* (1993) reported mylonite zones and en-echelon quartz-sulphide veins in the East Kemptville tin deposit. Corey and Horne (1989b) documented the close spatial association of brecciated and silicified rocks and Pb-Zn-Ba-Au-Ag mineral occurrences in the Little Tobeatic Lake area. The exact role of structure in some deposits remains somewhat contentious; however, most evidence indicates that there was some component of structural control on the localization of greisen-, vein- and

breccia-type mineralization.

It is clear from previous sections that greisen- and vein-type deposits occur throughout the entire batholith (Fig. 9.1). However, it should be noted that the largest greisen deposits (e.g. East Kemptville, Long Lake, Upper New Cornwall, Inglisville) are located at contacts between Stage II plutons and their metasedimentary country rocks. This has been interpreted by many authors (Richardson *et al.*, 1982; O'Reilly *et al.*, 1982; MacDonald and O'Reilly, 1989) to reflect 'ponding' of granite-derived hydrothermal fluids beneath an impermeable metasedimentary 'cap'. In contrast, the largest vein-type mineral occurrences (e.g. Millet Brook, New Ross) occur along northeast-trending structures in central portions of Stage I plutons, possibly above the buried cupolas of specialized granites.

Smith and Turek (1976) evaluated the economic potential of three composite plutons (mostly Stage II plutons with some adjoining Stage I rocks) using petrological indices and geochemical parameters. They concluded that the three plutons had differing economic potential. Chatterjee (1983) proposed a series of metallogenic domains within the batholith based on the styles and elemental assemblages of all known mineral occurrences. The domains were established independent of the existing bedrock geology. Numerous occurrences have subsequently been found, both during the South Mountain Batholith project and by mineral exploration activities. The elemental associations and styles of these occurrences (Fig. 9.1) are generally consistent with the previously proposed metallogenic domains. In fact, MacDonald *et al.* (1992b) concluded that many of the domains of Chatterjee (1983) occur within one or more plutons with several domain boundaries corresponding to pluton margins. This suggests that individual plutons are directly responsible for their respective deposit types and associated suites of elements, presumably through prolonged crystal fractionation. Differences in the polymetallic character of the various domains probably reflect variations in bulk composition and physico-chemical conditions during emplacement and crystallization, and possibly varying amounts of crustal contamination during emplacement, within the various plutons of the batholith. If so, the economic mineral potential of each pluton should be considered individually, as suggested by Smith and Turek (1976).

### 9.5 Summary

Mineral exploration has been conducted in the South Mountain Batholith for more than



100 years. Early activities lead to the discovery of small polymetallic Sn-W occurrences and the former New Ross manganese mines, whereas an exploration 'boom' in the 1970s and 1980s resulted in the discovery of the East Kemptville (Sn-Cu-Zn-Ag) and Millet Brook (U-Cu-Ag) deposits and numerous additional polymetallic occurrences. All deposits can be classified into five main types. These include greisen, vein, breccia, pegmatite and peribatholithic deposit types. The first four types are defined on the basis of their mineralogy, attending alteration assemblages and field relations. In contrast, peribatholithic deposits are defined only on the basis of field relations and may represent mineralization types similar to the first four categories.

To date, only greisen- and vein-type deposits have proven to be economically viable. The potential for additional deposits of these types is considered excellent. A project designed to evaluate the potential of breccia-type deposits in the Little Tobeatic Lake area is currently being conducted as part of the 1993-96 Canada - Nova Scotia Cooperation Agreement on Mineral Development (Corey and Graves, 1993). Pegmatite-type deposits within the batholith are generally considered to have a low economic potential; however, the spodumene (Li)- and tourmaline-bearing Brazil Lake pegmatite (Fig. 9.12; MacDonald *et al.*, 1992a; Corey, 1994) may have potential as a source for industrial minerals (e.g. spodumene, feldspar) or gem quality minerals (e.g. blue tourmaline). The potential for peribatholithic deposits similar to the Duck Pond deposit and Caledonia occurrences is considered to be very high, particularly in the Southwest Nova Scotia Tin Domain, and merits future exploration.

The impetus for the South Mountain Batholith project was the potential for polymetallic mineral deposits, particularly in light of the increased exploration and development activity in the late 1970's and early 1980's. Accordingly, most of the work focused on polymetallic mineralization, however, there are several industrial mineral commodities that have excellent potential for development. Firstly, dimension stone quarries have been operated in the batholith and adjoining satellite plutons for more than 100 years. The wide range of colours, textures, grain sizes and mineralogy of the granitic map units coupled with wide joint spacing (i.e. > 1-10m spacing) in some regions of the batholith suggest excellent potential for future dimension stone development. The rock units also have excellent potential for crushed aggregate for various applications. The glacial sediments overlying the batholith have a wide range of compositions from well-sorted glacial outwash deposits of sand and gravel to large poorly sorted eskers.

extensive, proximally-derived ground moraines and distally-derived allocthonous drumlins and ground moraine (Finck et al., 1989). Many of these glacial deposits have been exploited for aggregate or sand and gravel and continue to have excellent potential for future development. Several minerals including alkali feldspar, muscovite, fluorite, topaz and beryl have good potential for industrial mineral applications. The economic viability of the above industrial mineral commodities have not been evaluated as part of the project but clearly merit further work.

## *Chapter 10*

### EXPLORATION METHODS

#### 10.1 Introduction

As previously noted, there has been sporadic mineral exploration for polymetallic mineralization in the South Mountain Batholith since the late 1800's. Initial activities consisted of prospecting and boulder tracing which led to the discovery of the New Ross Manganese Mines and numerous polymetallic occurrences, mainly near the village of New Ross. Recent exploration programmes, primarily since the mid 1970's, combined basic prospecting with a wide variety of geochemical and geophysical surveys, most notably till geochemistry and airborne gamma-ray spectrometric (i.e. "radiometric") surveys. This activity led to the discovery of the East Kemptville Sn-Zn-Cu-Ag and Millet Brook U-Cu-Ag deposits. This section summarizes the methodology used for mineral exploration to date and outlines a recommended strategy for future exploration surveys.

#### 10.2 Geochemical Data

The basic premise for exploration geochemistry is that ore deposits are enriched in a suite of elements relative to host- or cover-rocks and that this enrichment is detectable in various sample media near, and over, the deposit. There are four mineralization types in the batholith, as outlined above, each with its own characteristic assemblage of ore, gangue and alteration minerals and subsequently its own elemental assemblage. These include: 1) Greisen - Sn, W, Mo, As, Cu, Pb, Zn, Bi, Au, Ag, B, F, P, Na and K; 2) Vein - U, Cu, Mn, P, F, Ag; 3) Breccia - Pb, Zn, Ba, Sn, W, Au and Ag; 4) Pegmatite - Mo, Sn, W, Cu, Nb, Ta, Be, B, F and Li. It is important to note that individual deposits may not be enriched in all of the elements associated with the particular style of mineralization. In addition to the detection of individual mineral deposits, geochemical data can also be used to delineate metallogenic domains (Chatterjee, 1983) and "specialized" leucogranites, both having characteristic enrichments and/or depletions in granophile elements that are variably reflected in the surficial sampling media (MacDonald et al., 1992b).

There have been several types of geochemical surveys conducted over the batholith since the 1950's (Rogers and Lombard, 1990). The following sections discuss some salient aspects of

these surveys, with particular attention to their usefulness in exploring for granophile mineralization.

#### 10.2.1 Stream Sediment Surveys

The first regional/reconnaissance geochemistry over the batholith consisted of a stream sediment survey conducted by the Geological Survey of Canada (Boyle et al., 1958). Samples collected during this survey were analyzed for Cu, Pb and Zn in the field using the organic reagent dithizone. The results from this survey are not particularly useful for granite related mineralization because of the limited suite of elements and the scarcity of samples from the interior regions that are dominated by granitic rocks.

In general, the physiography over much of the batholith is typified by low-lying or hummocky terrane with sluggish meandering streams that do not have abundant sediment. As a consequence this area is not conducive for stream sediment surveys. In contrast the northern margin of the batholith along the northern edge of the South Mountain is cut by incised streams which are well suited for stream sediment surveys.

#### 10.2.2 Lake Sediment Surveys

In general, private-sector companies did not use lake sediment surveys when exploring for granite-hosted mineralization. Conversely the Nova Scotia Department of Mines and Energy conducted a centre lake-bottom survey over the entire Meguma Zone (Bingley and Richardson, 1978). Lake sediments reflect the collective response of the bedrock, and perhaps more importantly, the till in a catchment basin. Thus a single lake sediment sample may be representative of a large area. The chief advantage of lake sediment surveys, compared with other types of regional geochemical surveys, is that they are easy to conduct, particularly if helicopter support is available to the explorationist. Another advantage is the relatively uncomplicated sample preparation procedures consisting essentially of drying and sieving the sediment or gytja prior to analysis. The elimination of complex and costly sample preparation procedures reduces the possibility of contamination. The chief drawback with lake sediment surveys is the lack of geological information that is available from the sample medium. For example it is not possible to establish the exact bedrock or till compositions within the catchment basin by examining collected samples.

The samples collected during the Bingley and Richardson (1978) survey were first

analyzed for a suite of 15 elements including Cu, Pb, Zn, Ag, Fe, Mn, As, Mo, U, Cd, Ba, F, Sr, Ca, Mg and Loss On Ignition (LOI). With the exception of U, F and possibly Ba these elements are not particularly useful for detecting granophile mineralization. In light of this the entire sample set was re-analyzed for a suite of 16 elements including the "granophile elements" Sn, W, Li, Rb, F and Nb (Rogers et al., 1985). Figures 10.1 and 10.2 are plots of Sn and Cu for lake sediments over southwestern Nova Scotia. The boundaries of Stage I and II plutons and the metallogenic domains of Chatterjee (1983) have been plotted on these diagrams for comparison.

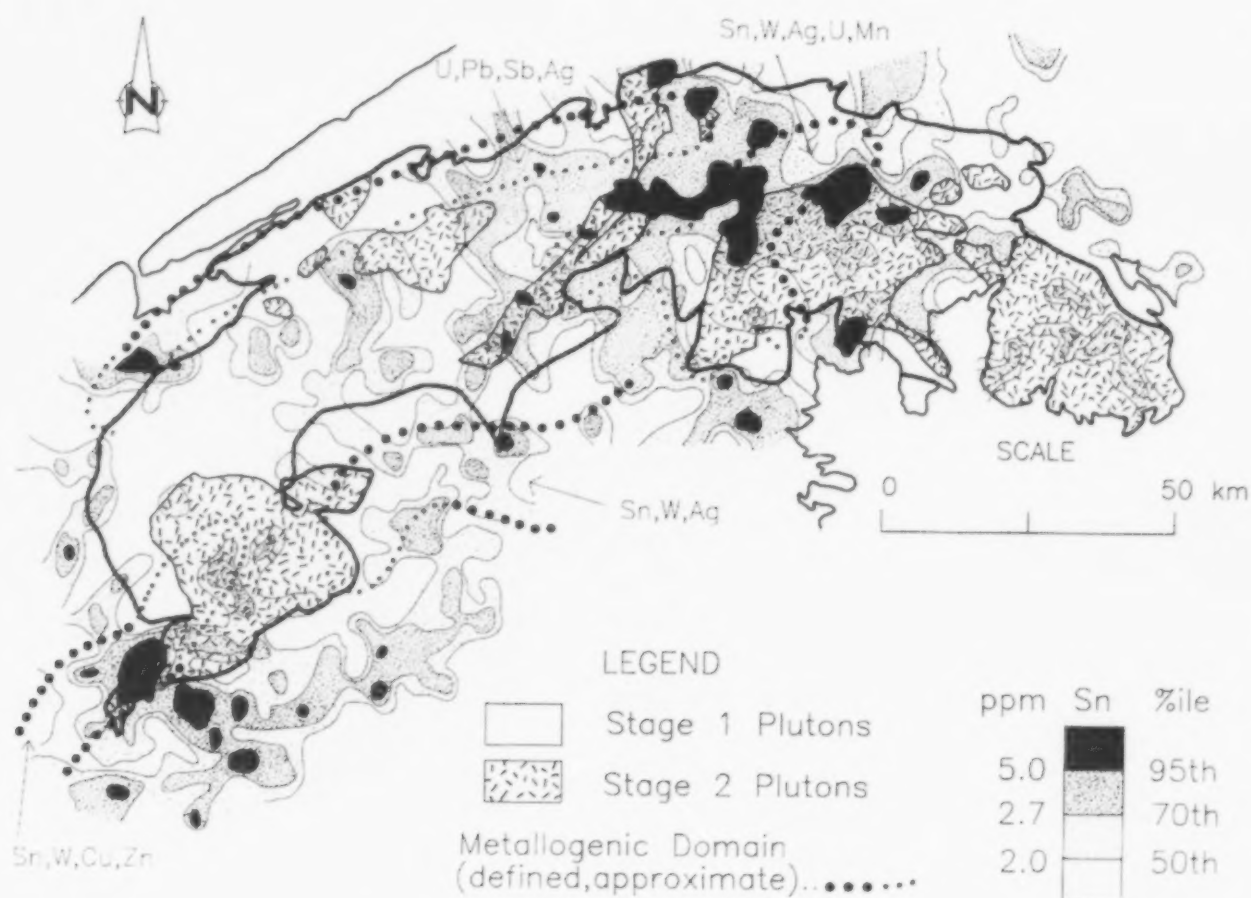


Figure 10.1 Contoured plot Sn in lake sediment data from southwestern Nova Scotia (modified after Lombard, 1991). Contour intervals based on percentile values for the entire Meguma Terrane data set and were arbitrarily selected at the 50th, 70th and 90th percentile levels. The metallogenic domains of Chatterjee (1983) and the Stage I and II pluton boundaries from this study have been plotted for comparison.



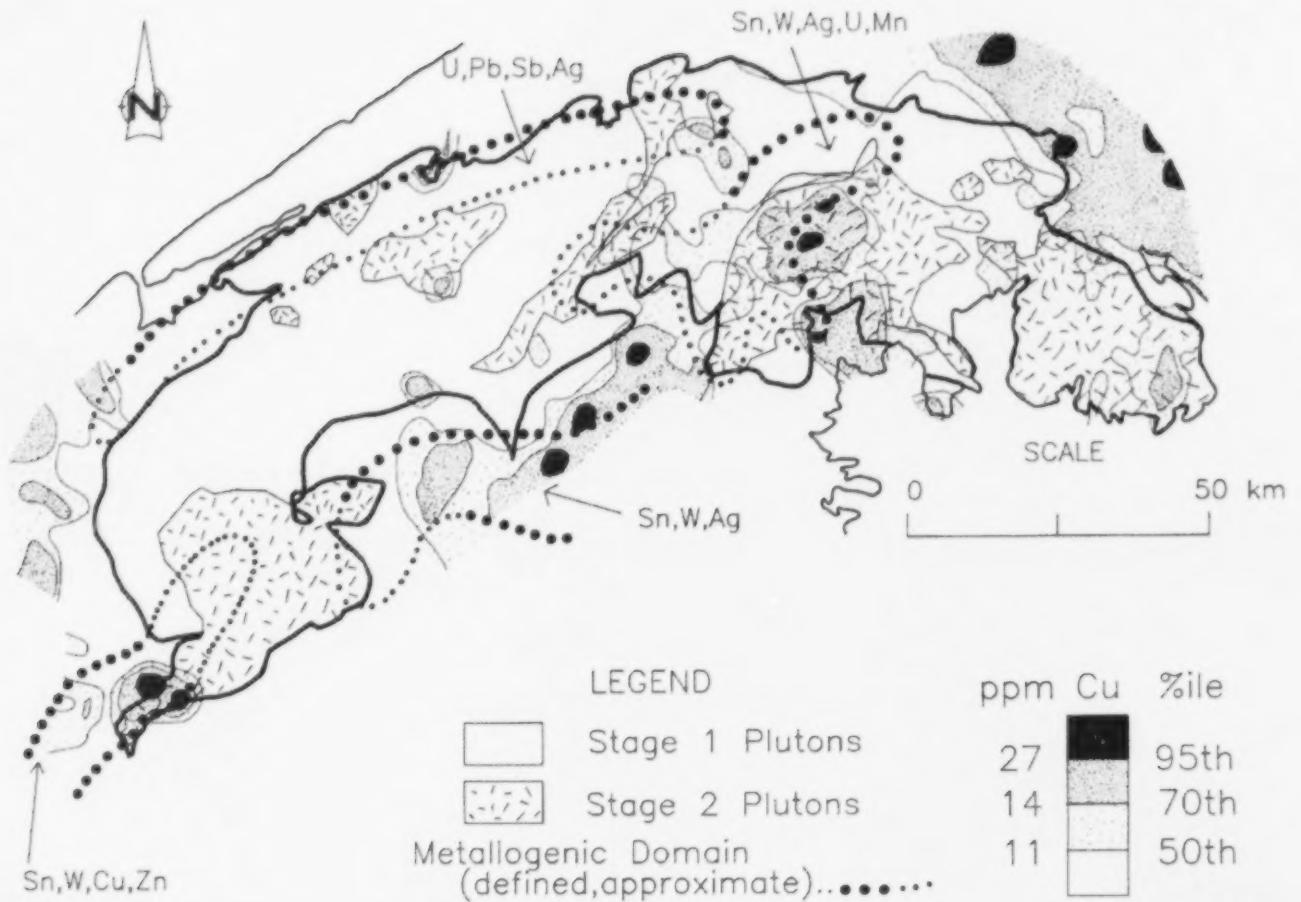


**Figure 10.2** Contoured plot Cu in lake sediment data from southwestern Nova Scotia (modified after Lombard, 1991). Contour intervals based on percentile values for the entire Meguma Terrane data set and were arbitrarily selected at the 50th, 70th and 90th levels. The metallogenic domains of Chatterjee (1983) and the Stage I and II pluton boundaries from this study have been plotted for comparison.

An examination of the centre-lake bottom data (Rogers et al., 1985; Lombard, 1991) reveals large geochemical contrasts throughout the batholith, which may be attributed to several bedrock geological features. For example high Sn values are associated with granite-hosted mineralization at East Kemptville, as previously noted by Rogers and Garrett (1987), and near New Ross, an area that hosts numerous occurrences including Turner Tin and Grassy Brook.

In addition high Sn values are present in the Bezanson Lake area, which was flagged as having significant potential for granophile mineralization by Finck et al. (1988). In contrast, there are large portions of the batholith that have no known Sn occurrences and are outside the polymetallic Sn domains of Chatterjee (1983), that have high lake Sn values, such as the anomaly in the central part of the batholith (Fig. 10.1) that spans 3 Stage I and 2 Stage II plutons. The source for these high Sn values is unclear. The highest Cu values are mainly in lakes that overly the Meguma Group metasediments and Carboniferous cover rocks. Within the batholith, the highest Cu values are mainly in the New Ross area and near the East Kemptville and Long Lake deposits and, as such, there is an approximate correlation to metallogenic domains (Rogers et al., 1985). The distribution of Rb, Li, F and other "granophile" elements may be erratic, however, highest concentrations are primarily in lakes over Stage II plutons, particularly the New Ross Pluton, the southwestern portion of the Davis Lake Pluton and parts of the East Dalhousie Pluton.

Rogers et al. (1990) noted that multi-element lake sediment plots more accurately reflected the metallogenic domains defined by Chatterjee (1983) compared with single element lake sediment plots. The distribution of multi-element anomalies involving the granophile elements F-Li-Nb-Rb $\pm$ Sn is shown in Figure 10.3. Clearly there is a good correlation with the domains of Chatterjee (1983).

### 10.2.3 Till Surveys

Till geochemical surveys were the most common exploration method employed by private-sector companies during the exploration "boom" of the 1970's and 1980's. The results of these surveys are contained in a plethora of assessment reports in the DNR library. Several till stratigraphy and till geochemical studies over the entire batholith were also conducted by the Nova Scotia Department of Mines and Energy during this same time period. The following section focuses only on the results from the government surveys.

The majority of the surface of the batholith is blanketed by glacial till which was formed by glacial erosion of local bedrock and, in some areas, previously deposited till sheets. Much of the batholith is overlain by a stony local till with up to >90% locally-derived clasts that were dispersed 1-4 km. Finck et al. (1989) concluded that the "renewal distances" in these "local" tills was as low as 100 m. Other parts of the batholith are overlain by more distally derived tills,

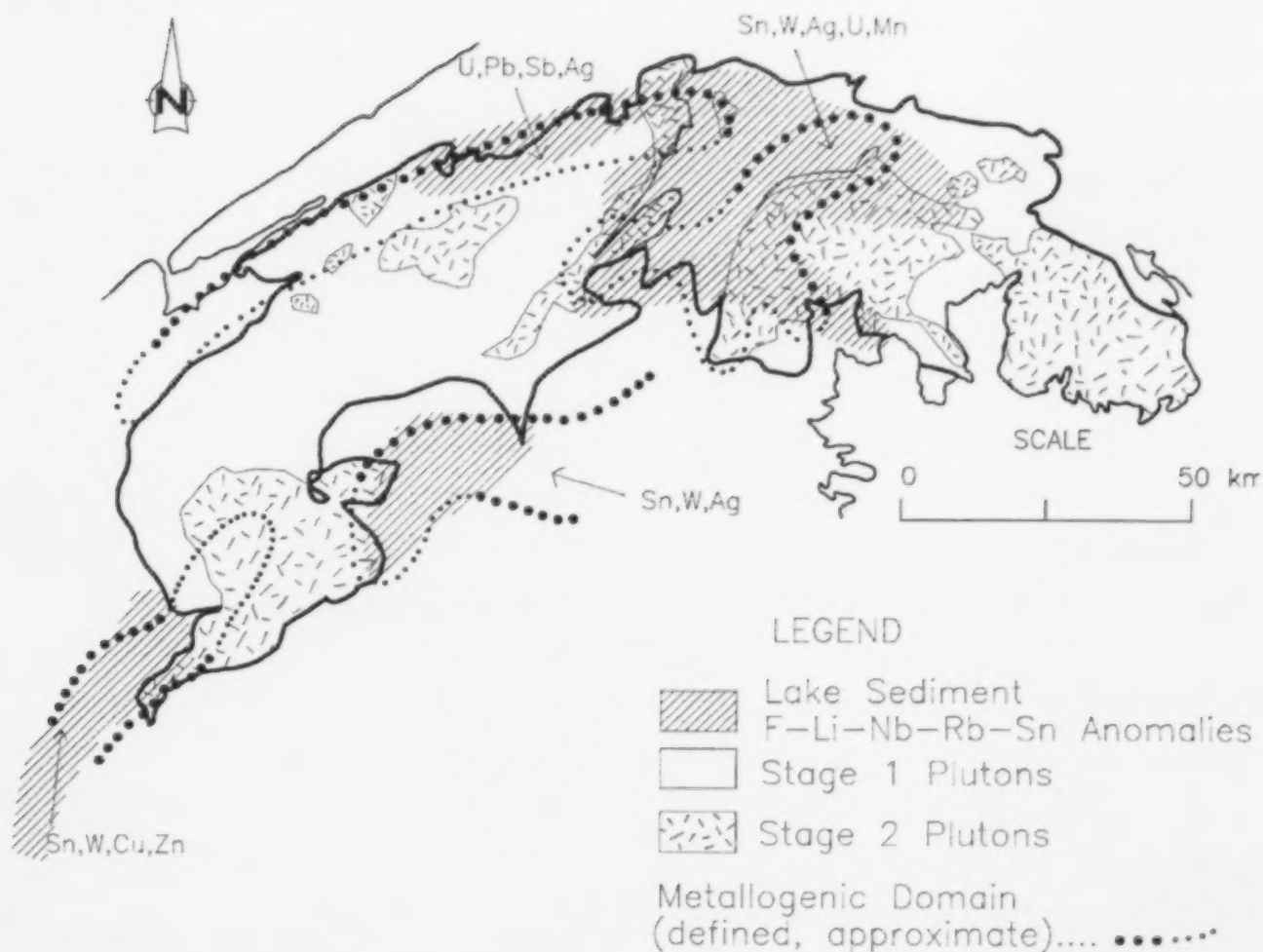


**Figure 10.3** Plot of multi-element centre-lake bottom "anomalies" for the South Mountain Batholith. Only anomalies involving the granophile elements  $F-Li-Nb-Rb \pm Sn$  are plotted. The metallogenic domains of Chatterjee (1983) have been plotted for comparison. See text for discussion.

most notably the Lawrencetown till (Stea and Fowler, 1981), which may have clasts that originated in excess of 20-50 km north of the Meguma Terrane (Stea and O'Reilly, 1982) although these tills usually have small percentages of locally-derived (i.e. < 1-2 km) clasts and matrix (Finck et al., 1989). Therefore the geochemical characteristics of the various till sheets that overly the batholith vary in response to their respective provenances. Thus caution should be exercised

when using till geochemistry in mineral exploration as noted by Graves et al. (1988). The main advantage to till surveys is that, unlike lake sediment surveys, individual till samples contain clasts that provide information about the till source area (i.e. provenance). The chief disadvantage to till surveys is the increased sampling time and costly/complex sample preparation procedures that increase the possibility of contamination (MacDonald et al., 1992b).

Till surveys were first conducted over batholith by Stea (1983), Stea and Fowler (1981) and Stea and Grant (1982). These workers analyzed till samples for a suite of 13 elements including Cd, Ag, Cu, Pb, Zn, Ni, Co, Mg, As, U, Mo, Sn and W. Stea and O'Reilly (1982) noticed that there were significant chemical differences between the various till sheets. Furthermore, they noted that most Sn and W "anomalies" in the heavy mineral separates were situated at the margins of the batholith at the granite/metasedimentary rock contact. They also observed that most of the W anomalies were in the northern and eastern sections of the batholith whereas most Sn anomalies were in the southern part of the batholith which they regarded to reflect regional metallogenic zonation.

The entire South Mountain Batholith was covered by a till survey with a sampling density of 1 per 4 km<sup>2</sup> (Finck et al., 1990a,b). As noted above this survey was conducted in concert with the bedrock geological mapping and was designed to help define geological contacts and act as an aid to mineral exploration. Approximately 2100 till samples were analyzed for a suite of 16 elements including Ni, Cr, Ba, Th, Sc, As, Rb, Sb, Ta, U and W by neutron activation (INAA) and Pb, Zn, Cu, Fe and manganese by atomic absorption (AAS). Analytical results are given in Boner et al. (1990). In addition, tin (Sn) analyses for heavy mineral concentrates from the same suite of 2100 samples were given by Finck et al. (1990a,b). Despite the presence of several till sheets over the batholith, as noted above, there is a very good correlation between bedrock type and the relative abundances of several "granophile" elements. For example the concentration of Ta in tills derived from Stage II plutons is markedly higher than for Stage I plutons (Fig. 10.4). Conversely, the distribution of U and Th, which reside mainly in the accessory minerals zircon and monazite, does not reflect the type of underlying bedrock but rather can be correlated to the degree of bedrock weathering (Finck pers. comm.). The distribution of Cu, Pb, Zn and As generally do not reflect the distribution of Stage I and II plutons. These elements mainly reflect

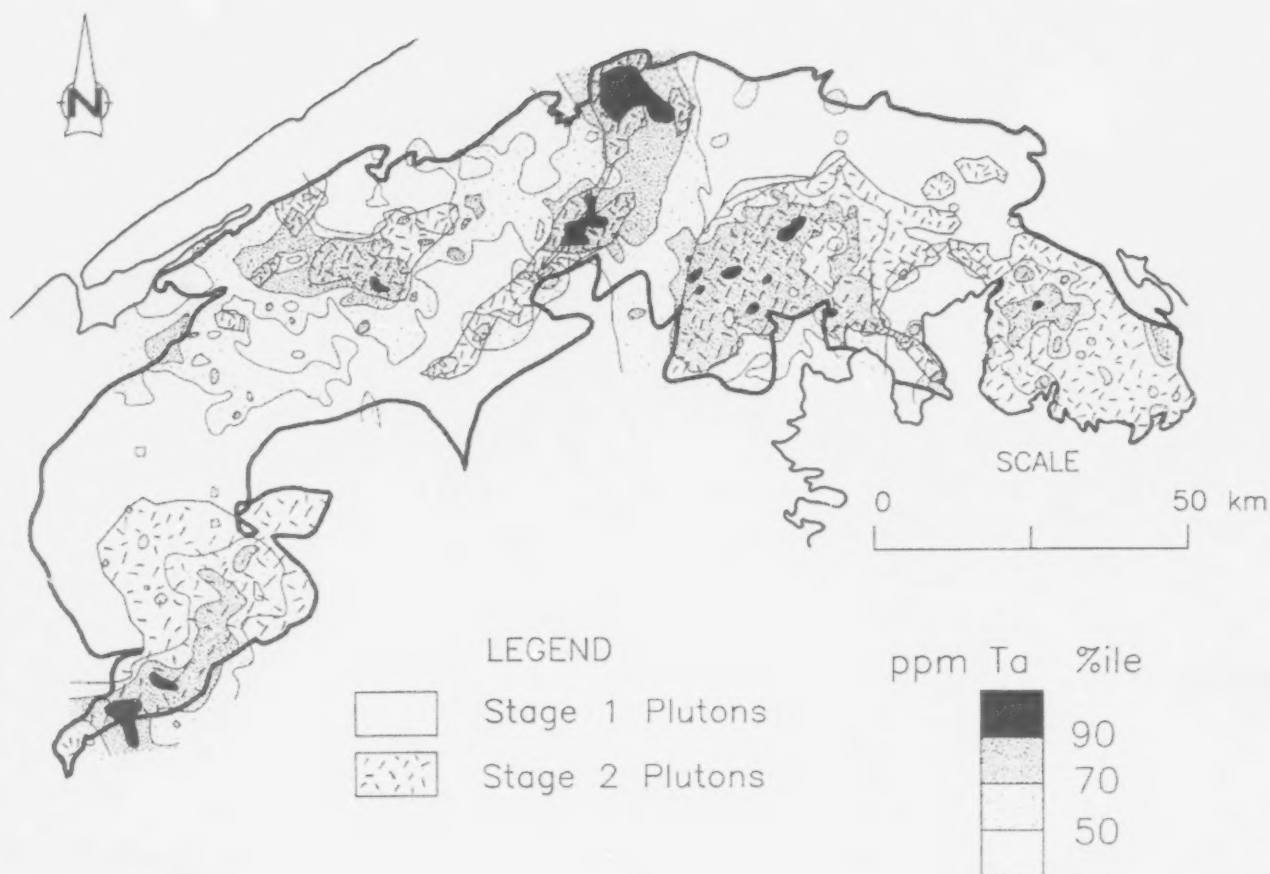


**Figure 10.4** Plot of the distribution of Ta in the -230 (-62.5 µm) fraction of whole till for the South Mountain Batholith (data from Boner et al., 1990). Contour intervals calculated using the entire data set. Note the strong spatial association between high concentrations of Ta in till and the distribution of Stage II pluton rocks.

the presence of sulphide mineralization as noted for the Halifax Pluton (Graves et al., 1988) but may also reflect the degree of weathering of bedrock (Finck pers. comm. 1993).

Perhaps one of the most striking feature of the geochemistry of the tills over the batholith is the distribution of Sn in heavy mineral concentrates (Finck et al., 1990a,b). All of the areas with high concentrations of Sn (i.e. >90<sup>th</sup> percentile for entire data set), including the East Kemptville, East Dalhousie, New Ross, Long Lake and Bezanson Lake areas (Fig. 10.5), have associated polymetallic Sn occurrences or deposits. Till geochemistry is therefore considered to be a very effective exploration tool.

The East Kemptville area has concentrations of Sn that overshadow the remainder of the



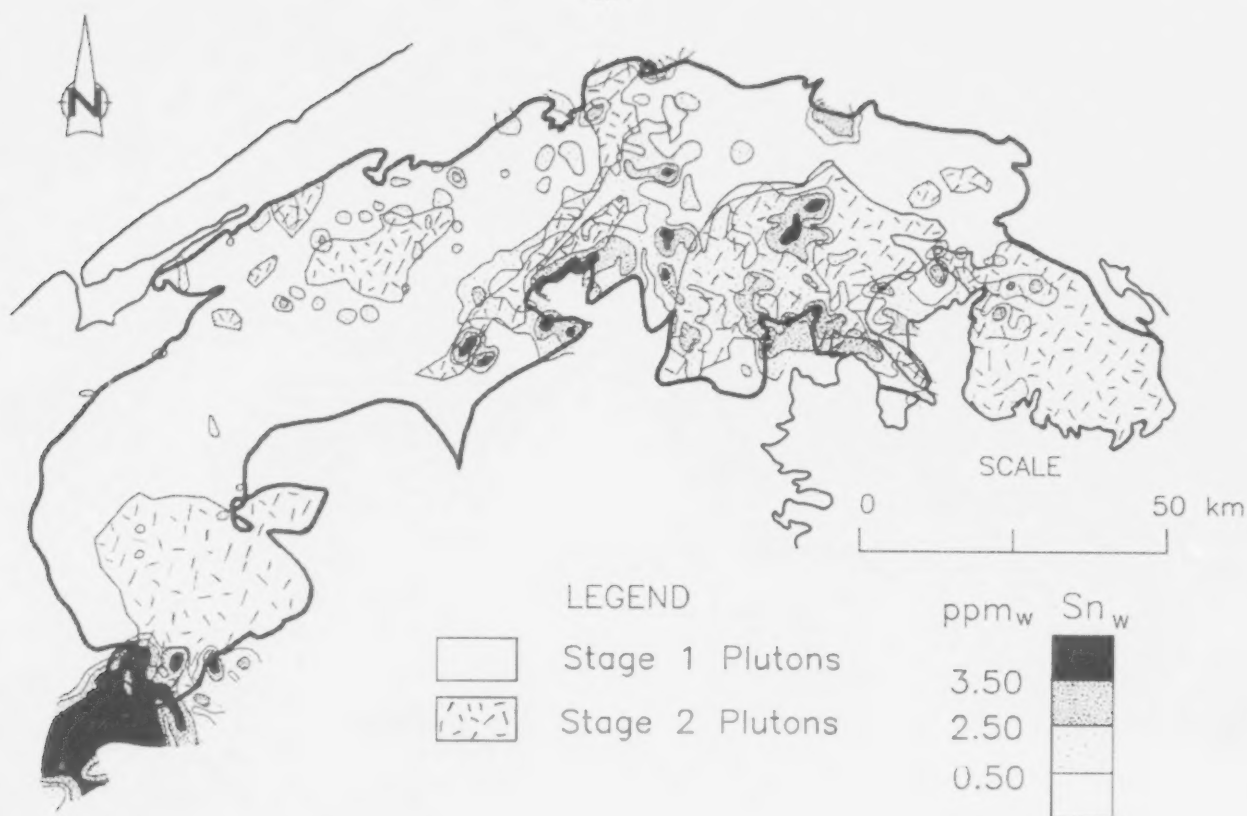


Figure 10.5 Plot of the distribution of "weighted" Sn values in heavy mineral separates from the  $-60 + 230$  ( $-250 + 62.5 \mu\text{m}$ ) mesh fraction of till from the South Mountain Batholith (data and weighting method from Finck et al., 1990a; 1990b). Contour intervals calculated using the entire data set.

batholith. A detailed plot of the distribution of Sn in heavy mineral separates in till from the southwestern portion of the Davis Lake Pluton is given in Figure 10.6. Weighted Sn values are mainly  $> 5$  ppm with maximum values of  $> 80$  ppm compared with the rest of the batholith where the 98<sup>th</sup> percentile is  $3.50 \text{ ppm}_w$  and the maximum value is  $10.66 \text{ ppm}_w$ . In fact if the percentile values were defined for the batholith using a subset of data from this region, none of the samples from the rest of the batholith would be "anomalous". The distribution of these high Sn values define the southwestern Nova Scotia Tin Domain as first described by Chatterjee (1983) and further investigated by Kontak et al. (1990). These extremely high Sn values near East Kemptville presumably reflect the presence of the East Kemptville Sn deposit, however, this deposit is situated on the top of a prominent ridge that presumably underwent significant erosion and glacial dispersion. The relatively low Sn values elsewhere in the batholith may not necessarily reflect



**Figure 10.6** Plot of the distribution of "weighted" Sn values in heavy mineral separates from the -60+230 (-250+62.5  $\mu$ m) mesh fraction of till from the southwestern portion of the Davis Lake Pluton (data and weighting method from Finck et al., 1990b). Contour intervals arbitrarily chosen to best display the entire data range.

low Sn potential but rather a lack of extensive glaciation of Sn mineralization.

In general, till geochemical data when interpreted with stratigraphic and provenance information can be used to define discrete exploration targets. In addition, follow-up surveys using a much closer spacing than 2 km can be used to define targets for trenching and diamond drilling as shown by the detailed work of MacDonald et al. (1992). Despite the presence of distally-derived tills the abundance of Ta and Rb and possibly other "granophile" elements can be used to define the extent of geochemically "specialized" granites.

#### 10.2.4 Biogeochemical surveys

Biogeochemical surveys were not used to explore in the batholith by exploration companies. In fact, the applicability of biogeochemical methods for granite-hosted mineralization in the Meguma Zone was investigated only in the 1980's and 1990's. The chief advantages of biogeochemical surveys are their ease of sampling uncomplicated sample preparation procedures that reduce the risk of contamination. The main drawback to biogeochemical surveys is the lack of geological information that can be gleaned from samples as previously noted for lake sediment surveys.

The first biogeochemical study in the batholith was by Brooks et al. (1982) at the Millet Brook U-Cu-Ag vein-type deposit. They measured the U concentrations in Red Spruce and three species of hardwood trees over mineralized zones at the deposit. Results were then compared with U data for "B" horizon soils and scintillometer data over the same areas. They noted "anomalous" concentrations of U in Red Spruce that compared favourably with the scintillometer and bedrock geological information. Relatively poor analytical results were obtained for all investigated hardwood species. On the basis of the marked contrast between the U levels over mineralized/unmineralized biotite granodiorite Brooks et al. (1982) concluded that biogeochemical techniques could be successfully applied in U exploration.

Dunn et al. (1989) conducted a regional biogeochemical survey in eastern Nova Scotia. Their data confirmed the presence of known Au deposits and indicated that these techniques could be applied throughout the Meguma Zone. Therefore a regional biogeochemical survey was initiated over the southwestern part of the Meguma Zone (Dunn et al., 1992). The data from this survey revealed extreme enrichment in many "granophile" elements (e.g. Sn, W, Ta, Cs, Rb, Li) in the area from the East Kemptville deposit to the southern granite/metasediment contact. This enrichment is depicted in the plots of Sn and Rb in Red Spruce bark (Figures 10.7 and 10.8). Of particular interest is the discrepancy between the Sn patterns in Red Spruce and the distribution of Sn in the heavy mineral separates from till (Fig. 10.5). A detailed discussion of these differences is beyond the scope of this report.

MacDonald et al. (1992) analyzed Balsam Fir branches as part of a multi-media geochemical study of the Brazil Lake (Li, Be) pegmatites. They noted that branches from Balsam

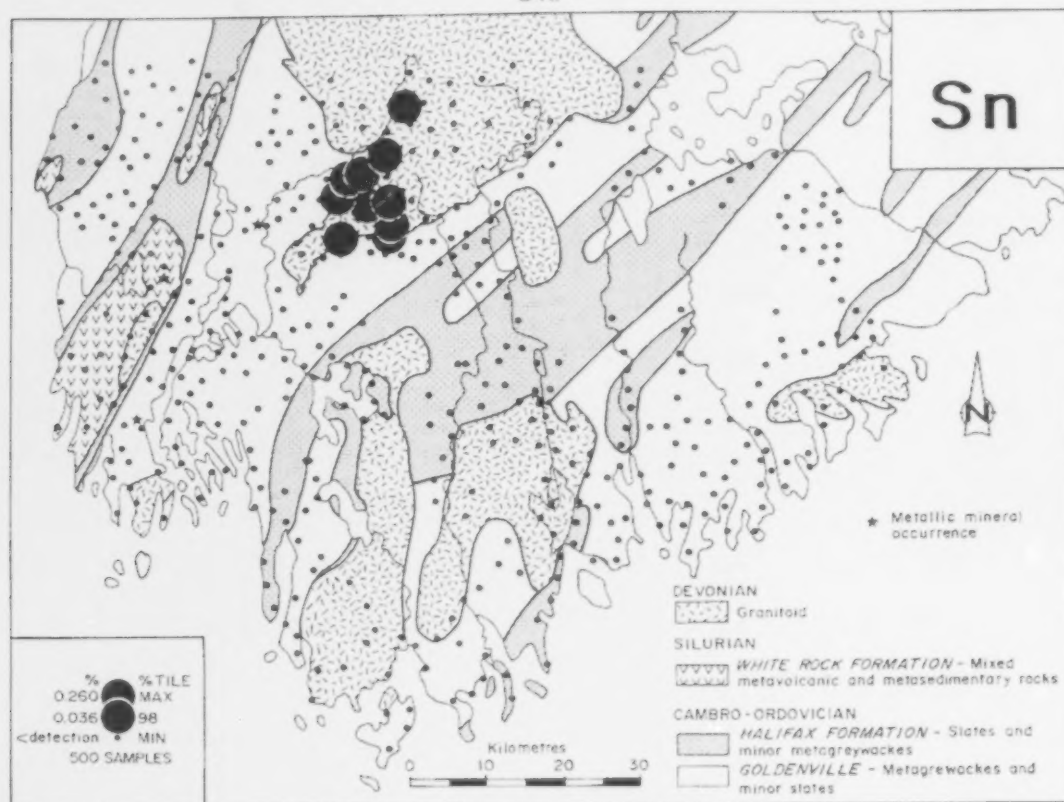


Figure 10.7 Proportional symbol plot showing the distribution of Sn in red spruce bark in southwestern Nova Scotia (modified from Dunn et al., 1992). The simplified geology for this area has been plotted for reference.

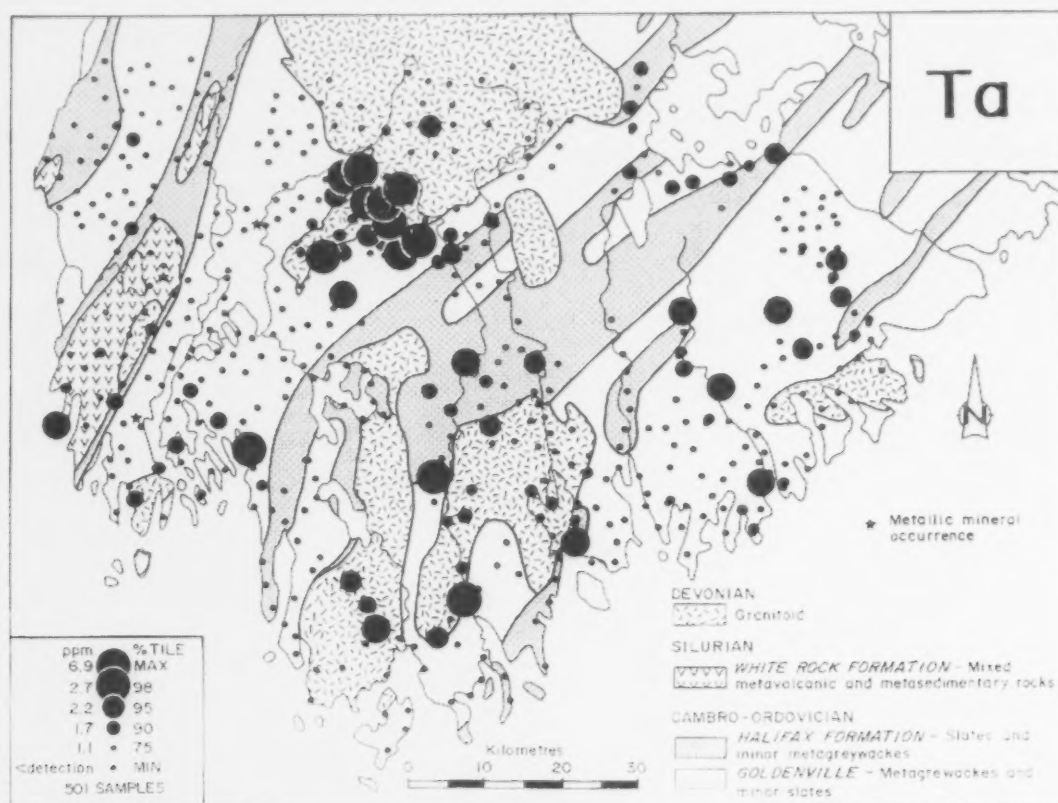


Figure 10.8 Proportional symbol plot showing the distribution of Rb in red spruce bark in southwestern Nova Scotia (modified from Dunn et al., 1992). The simplified geology for this area has been plotted for reference.

Fir trees collected near the pegmatite outcrop in the Brazil area generally had much higher values of  $\text{Li} \pm \text{Cs} \pm \text{Ta} \pm \text{P} \pm \text{Sn} \pm \text{Nb} \pm \text{F}$  than samples taken in other parts of the study area. They also noted different spatial distribution patterns for Li, Be and Cs which was tentatively attributed to primary zoning in the pegmatites.

It is apparent from the aforementioned studies that chemical analysis of plant tissues is an effective method for delineating areas of bedrock and overlying till that are enriched in "granophile", and indeed "chalcophile", elements. In addition these techniques have successfully confirmed the presence of known granite-hosted mineral deposits and metasediment-hosted rare-metal pegmatites in the southern Meguma Zone. Therefore biogeochemical techniques can be used in exploration programs for granite-hosted mineralization.

#### 10.2.5 Lithogeochemical data

The South Mountain Batholith project has produced a large lithogeochemical database, as outlined in Chapter 5. Exploration companies routinely collected hand samples for geochemical analyses to measure the concentration of ore elements, or characteristic trace elements, that would suggest the potential for mineralization. However, to date there have not been any systematic exploration lithogeochemical studies for the batholith. Thus an evaluation of the potential for this type of exploration is warranted.

As previously noted in Chapter 5, lithogeochemical data can be used to define normal and/or reverse compositional zoning in most Stage I and II plutons. The central "highs" in normally zoned Stage II plutons generally have the highest concentrations of "granophile" elements and therefore are the most "specialized" granites exposed in the batholith. The detection of these rocks using lithogeochemical techniques is therefore a useful exploration method.

The remainder of this discussion will focus on the Davis Lake Pluton, however, all plutons can be investigated using lithogeochemistry. The Davis Lake Pluton displays very systematic normal zoning as previously noted in Chapter 5. For example K/Rb values (Fig. 5.10) decrease from  $>200$  along the northern and eastern margin to  $<50$  in the southeastern lobe which hosts the East Kemptville deposit. Detailed contour plots of F and Rb for the East Kemptville and western Davis Lake Pluton are given in Figures 10.9 and 10.10. These data indicate normal zoning in the Davis Lake Pluton with the least "evolved" rocks along the eastern and northern





margins having the lowest concentrations of F and Rb and the most evolved rocks with the highest levels of F and Rb residing in the southern lobe. In fact the contours for F and Rb have a pronounced "bulls-eye" pattern that is centred on the East Kemptville leucogranite and the greisen-type Sn-Zn-Cu-Ag mine. An exhaustive discussion of the exact processes that lead to the extreme enrichments of F and Rb and the pronounced lowering in K/Rb values over the Sn mine and host leucogranite is beyond the scope of this report. However, the key observation is that lithogeochemical analysis of the rocks of the Davis Lake Pluton accurately pin-point the East Kemptville deposit and thus should be considered as a viable "tool" when designing future exploration programmes, particularly for greisen-type mineralization which is spatially associated with "specialized" granitoid bodies.

#### 10.2.6 Humus surveys

Organic humus or A<sub>1</sub> soil layer has not been used extensively for exploration for granophile mineralization. In fact the only published reference for humus data is MacDonald et al. (1992b) for the Brazil Lake pegmatites. They noted that levels of most elements including Li, Be, Cs, F, Rb and Sn varied significantly in the humus samples collected throughout their 600m x 600m sampling grid. They concluded that a large proportion of this variation in concentration correlated to the organic content of the samples which ranged from 5-90% and subsequently applied a correction factor to the raw analytical data, based on the percentages of organic material.

A plot of Li (corrected for organic content) in humus from the Brazil Lake survey is given in Figure 10.11a. Clearly the highest Li values are in humus samples collected directly over the known spodumene-bearing pegmatites. The results for Be, Cs and Ta (Figs. 11 b,c,d) are less definitive but also mirror the location of known pegmatite occurrences. High concentrations of these "granophile" elements elsewhere in the sample grid suggests that additional pegmatite dykes are also present. The most significant finding from this study, in terms of the implications for mineral exploration, is that anomaly/background contrast can be easily detected in samples of organic humus. The results from a previous multi-media geochemical study over the Yava Pb deposit in eastern Cape Breton Island (MacDonald et al., 1991) revealed that the distribution of Pb, Zn and other heavy metals in humus is strongly influenced by hydromorphic processes. Therefore, the applicability of humus sampling for the entire batholith is yet to be evaluated but merits further evaluation.

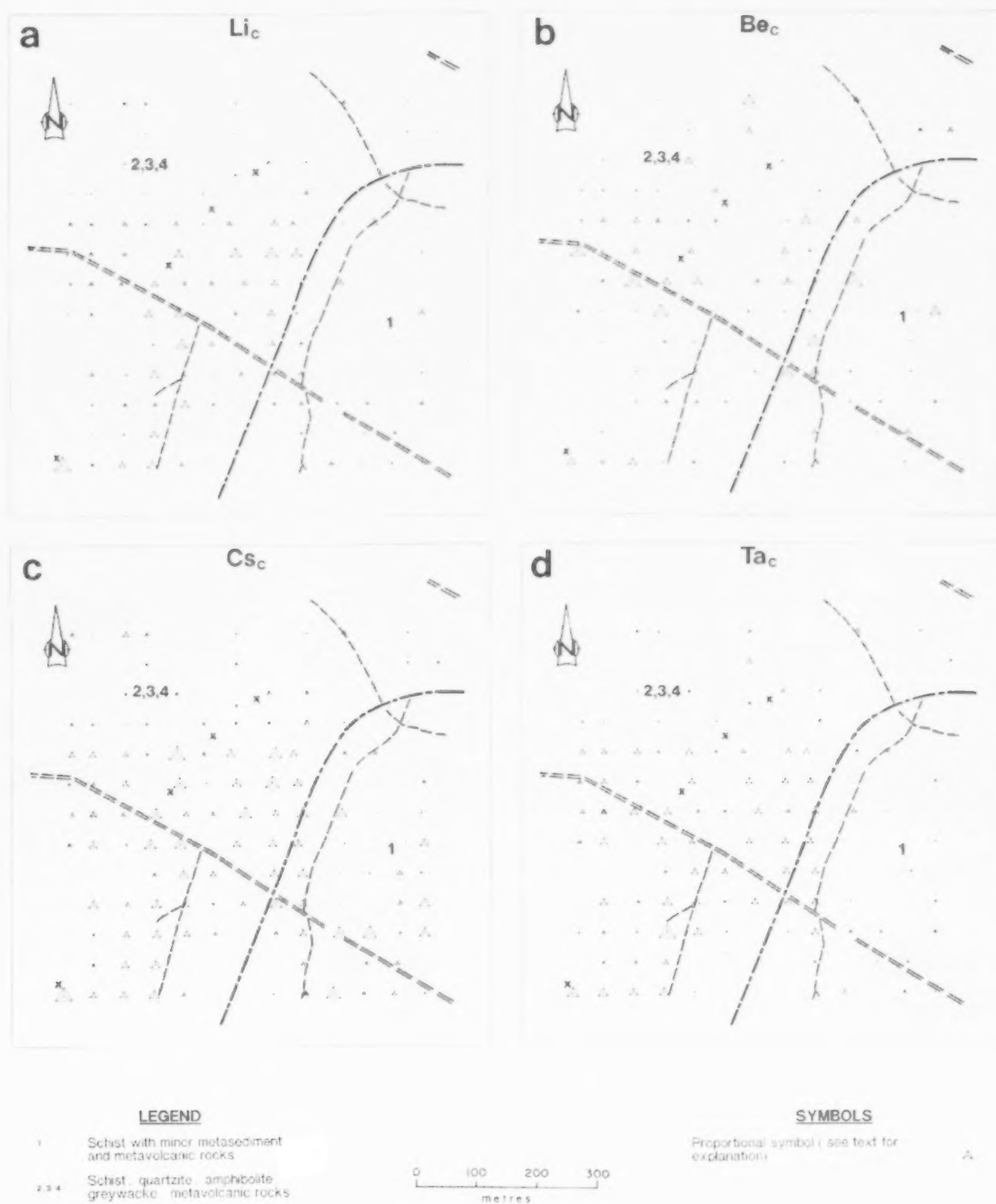


**Figure 10.11** Proportional symbol plot for humus ash (corrected data from MacDonald et al., 1992b) from the Brazil Lake area that hosts spodumene±beryl-bearing pegmatites. Note the close spatial relationship between the high Li concentrations in humus and the outcrop of rare-metal pegmatites.

### 10.3 Geophysical Data

Several geophysical techniques have been used by explorationists and government organizations over the granitic rocks of the South Mountain Batholith and other plutons of the Meguma Zone. By far the most widely used geophysical methods have been airborne gamma-ray spectrometry, however, other methods have been employed with varying degrees of success. The following section summarizes some of the applications of geophysical methods in the batholith.

#### 10.3.1 Airborne Gamma-ray Spectrometric Surveys

Airborne gamma-ray Spectrometric surveys were flown over the entire province between 1976 and 1990 (Ford et al., 1992). These surveys report responses both as total count (TC) and -as individual element components including equivalent uranium (eqU), equivalent thorium (eqTh) and equivalent potassium (eqK) and the various ratios of these components. The relationship between the results of these surveys and bedrock and surficial geology have been addressed in several studies including Chatterjee and Muecke (1982), Ford and Ballentine (1983), Ford and O'Reilly (1985), O'Reilly et al. (1988), and Finck et al. (1988). Spectrometric surveys over the granitic rocks of the Meguma Zone were also used by private sector companies, primarily in the search for U mineralization.

It is generally agreed by the above authors that the "radiometric" responses from the Geological Survey of Canada data can be explained by a combination of bedrock and surficial geological features. For example, most of the Stage II plutons, which are enriched in U and K compared with Stage I plutons, are clearly defined by several responses including eqU, eqK and eqU/eqTh. In addition, cryptic normal and reverse compositional zoning within both Stage I and II plutons, such as in the Halifax, Salmontail and New Ross plutons (MacDonald and Horne, 1988; Horne et al., 1989; MacDonald et al., 1992) are also evident in much of the "radiometric" data.

Complex "radiometric" patterns in some parts of the batholith and other Meguma Zone are difficult to explain in terms of the observed granitic rock types (O'Reilly et al., 1988). Some of these patterns reflect the presence of large scale alteration features including albitization and K-feldspathization or highly specialized leucogranite bodies (Chatterjee and Muecke, 1982; O'Reilly et al., 1988; Ford, 1993). In other areas observed radiometric patterns are best explained by the

dispersion of granitic and non-granitic lithologies in the complex series of Pleistocene deposits that overlie the batholith (O'Reilly et al., 1988; Finck et al., 1988).

Spectrometric data can be used at various scales to interpret different bedrock and surficial features. On a large scale data can be used to define batholith- and pluton-scale compositional trends. On a more local scale it can also be used to define individual granite/granite or granite/metasediment geological contacts (MacDonald et al., 1992). These data can also be used as exploration tools to delineate high response areas with intense greisenization, albitization and K-feldspathization associated with greisen-type and U-bearing vein-type mineralized zones such as the Millet Brook deposit (Chatterjee et al., 1982). In addition radiometric response can be used to define "specialized" leucogranites that may host pegmatite-type mineralization. Finally, the presence of intense alteration zones at the New Ross Mn-Mines (O'Reilly, 1992) indicates that radiometric data may be useful in outlining these types of vein-style deposits.

The chief draw-back with airborne gamma-ray spectrometric surveys is the difficulty in distinguishing between the contribution from each of the various geological features outlined above. For example an area of very high eqU and eqU/eqTh may reflect the presence of a "specialized" granite that may or may not contain mineralized or intense alteration zones. In addition the actual shape of the "anomaly" may have been changed significantly by glacial dispersion. Data from "radiometric" surveys must be evaluated in light of all of these factors.

#### 10.3.2 Other Geophysical Techniques

Several other geophysical techniques including electromagnetic (EM), very low frequency (VLF), resistivity, induced potential (IP) and gravity methods, have been employed, with varying degrees of success, over the batholith. Most techniques have been used by private-sector exploration companies, however, some government surveys have also been conducted.

Gravity data for the batholith mainly consists of the 6-km spaced regional data from the Geological survey of Canada (Miller and MacDonald, 1993). These data indicate the presence of two gravity "lows" centred over the Davis Lake and New Ross plutons which are interpreted as representing the thickest portions of the batholith. In general, detailed gravity surveys have not been used extensively in the batholith. The most notable exceptions include: 1) the delineation of a negative gravity "anomaly" near Caledonia by Billiton Canada (MacGillivray, 1982) which was



interpreted as representing a buried granite "cupola". This interpretation is consistent with the presence of polymetallic W-Sn-bearing quartz-greisen veins and associated breccia pipes and mineralized skarns (O'Reilly, 1985) in this area; 2) the recognition of an "inflection" in the granite/metasediment contact north of the East Kemptville Sn deposit which was interpreted to be an essential factor in the formation of the Duck Pond Sn deposit by Pitre and Richardson (1989).

As previously noted, the batholith does not contain magnetite or significant quantities of other minerals with high magnetic susceptibility. Accordingly, regional magnetic and vertical gradiometer surveys outline the batholith as an area of "flat" magnetic response, particularly, compared with the highly responsive Meguma Group metasedimentary rocks (Miller and MacDonald, 1993). Detailed magnetic surveys have not been extensively used for exploration in the batholith. However, magnetic techniques could possibly be used to explore for mineral deposits containing high modal proportions of hematite, most notably the vein-type deposits, and pyrite, such as some of the greisen- and breccia-type deposits. Magnetic techniques will probably not be applicable for delineating pegmatite-type mineral deposits.

Electrical geophysical methods including induced polarization (IP) and self potential (SP) have been successfully utilized to define sulphide- and oxide-bearing zones within the batholith. An example is the use of IP to identify the extent of sulphide zones along the trace of the Tobeatic Fault Zone near Little Tobeatic Lake (Corey and Horne, 1989c). Another example is the detection of arsenopyrite-bearing albitite dikes in the Upper New Cornwall area (Corey, 1983).

Electromagnetic (EM), very low frequency (VLF) and resistivity techniques are sensitive to subsurface "conductors" such as sulphide- and graphite-bearing zones and have been used effectively in the batholith. For example Corey (1983) identified alteration zones (albitization, greisenization) in the Upper New Cornwall area using VLF and resistivity surveys. VLF and EM methods are also very useful for identifying clay-rich horizons, such as at Millet Brook and the New Ross Manganese mines and the Little Tobeatic Lake breccia-type occurrence (McKenzie, 1988). Resistivity surveys are particularly effective for outlining the presence of water-bearing zones including the vein-type mineralization and associated fracture zones at the Millet Brook U-Cu-Ag deposit (Chatterjee et al., 1985).

#### 10.4 Discussion and Summary

Mineral exploration in the past several decades has focused principally on the potential for greisen- and vein-type mineralization throughout the batholith with sporadic exploration for breccia-type metal deposits along the southern margin of the Davis Lake Pluton (see discussion in Chapter 9). This activity has led to the discovery of the greisen-style polymetallic-Sn deposit at East Kemptville, the vein-type U-Cu-Ag deposit at Millet Brook, and numerous other occurrences. Most mineral occurrences have definitive geochemical and geophysical responses. The geochemical 'signatures' of the four main deposit types have been noted to reflect their different mineralogy and associated alteration mineral assemblages, subsequently, future geochemical programmes should consider utilizing statistical techniques to establish multi-element anomalies. This procedure may assist in differentiating between styles of mineralization, for example, it may be possible to distinguish F anomalies associated with vein-type mineralization (U-Cu-Mn-P-F-Ag) from greisen (Sn-W-Mo-As-Cu-Pb-Zn-Bi-Au-Ag-B-F-P-Na-K) or pegmatite (Mo-Sn-W-Cu-Nb-Ta-Be-B-F) by looking at the associated elemental assemblages.

Lake sediment surveys have been shown to reflect large-scale bedrock (and presumably till) features including metallogenic 'domains' (Rogers et al., 1990; Figure 10.3) and metal-rich regions of the batholith (e.g. New Ross, East Kemptville, Long Lake; Figures 10.1, 10.2). However, lake sediments will have limited application for detailed mineral exploration, owing to the relative size of the catchment basins and the nature of lake sediment depositional processes.

Till surveys have been shown to be an effective exploration method for pin-pointing the location of granite-hosted mineralization in the batholith, particularly when coupled with other geochemical and geophysical techniques (e.g. lake sediment geochemistry, Gamma-Ray Spectrometry). Explorationists have used detailed till surveys extensively to define trenching and drilling targets. Finck and Stea (1995) note that the surficial geology overlying the batholith comprises several till sheets with varying composition and proportions of distal (i.e. "foreign") and local components. It is critical that future till exploration programmes consider these factors into consideration, particularly when anomaly/background thresholds are established.

Biogeochemical techniques have not been used routinely for mineral exploration in the batholith, however, it is clear from initial studies and surveys that plant tissue can be used to

detect several different types of mineralization. Consequently, the potential of using biogeochemical techniques should be considered in future programmes, particularly in light of their relative cost-effectiveness.

Lithogeochemical analyses provides detailed information regarding primary dispersion and degree of fractionation in both Stage I and II plutons. Accordingly, this information can be used to target areas with potential for vein-type mineralization (e.g. New Ross Mn Mines) or greisen-type mineralization (e.g. East Kemptville deposit) that have been demonstrated to occur in highly fractionated parts of normally zoned plutons. Similarly, lithogeochemical analyses can be used to define individual bodies of highly fractionated leucomonzogranite and leucogranite that commonly host pegmatite- and greisen-type mineral deposits (e.g. New Ross area). Lithogeochemistry is not particularly suited for establishing target areas for breccia-type mineralization, which is fault-controlled and may cross-cut less fractionated granites and/or metasedimentary host rocks.

Geochemical analysis of organic soil (i.e. humus) can provide a cost-effective exploration method granite-hosted mineralization. However, geochemical analysis of ashed humus is particularly susceptible to the organic content of samples (MacDonald et al., 1992).

Geochemical procedures are not particularly useful for vein-type Fe-Mn mineralization, such as at New Ross Manganese Mines, because these deposits are not strongly enriched in many of the "granophile" elements such as U, Ta, Rb. It is difficult to use both Mn and Fe as diagnostic exploration elements because these elements are strongly affected by surficial hydromorphic processes and commonly are enriched in low-lying, swampy areas. It may be possible to remove the hydromorphic effects by some data correction procedure, possibly entailing the Loss on Ignition values which indicate the amount of organic content in each sample. It is possible that indicator elements may be established for this type of mineralization. For example, ore zones at New Ross Mn Mines have high modal proportions of fluorapatite and subsequently high concentrations of F and  $P_2O_5$ . The possibility of using these and other elements as pathfinder elements for Mn-Fe mineralization warrants evaluation.

Airborne Gamma-ray Spectrometric techniques are especially useful for vein-type U-Cu-Ag mineralization and can also be utilized to delineate specialized bodies that commonly host greisen- and vein-type mineralization. Spectrometric surveys may also be used to detect hydrothermal

alteration including potassic zones that routinely are associated with greisen-style mineral occurrences.

Vein- and breccia-type mineralization are localized along shear and fault zones, as evidenced by the Tobeatic Lake (Pb-Zn-Ba-Au-Ag) breccia occurrences, the Millet Brook U-Cu-Ag deposit and the New Ross Mn Mines deposits. Several geophysical techniques can be used to explore for these types of mineralization including VLF, IP, EM and SP.

Future exploration programs should employ a combination of geochemical and geophysical techniques and will assuredly benefit from the extensive datasets that have generated by both provincial and federal government surveys and organizations, along with mineral industry assessment work. Clearly, exploration programs that combine available bedrock and surficial geological information, geochemistry and geophysical data, and basic prospecting, should lead to the discovery of additional granite-related mineralization in or around the South Mountain Batholith.

*Chapter 11***SUMMARY AND CONCLUSIONS****11.1 Geology of the Batholith**

The South Mountain Batholith project was conducted as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement. The chief aim of the project was to evaluate the mineral potential of the batholith by conducting bedrock and surficial geological mapping and detailed follow-up studies. A comprehensive report outlining the results of the surficial mapping is given in Finck and Stea (1995). Bedrock geological maps were released as a series of 1:50,000 scale Open File and published maps, most with accompanying marginal notes. In addition, a 1:250,000 scale compilation map was published. A copy of this map is located in the pocket at the back of this report.

The project represents the first time that comprehensive geological mapping was conducted over the entire batholith. The classification scheme for subdividing the granitic rocks of the batholith was established prior to (MacDonald, 1985), and in the early stages of the project (MacDonald et al., 1985). This scheme combines several macroscopic attributes of the various granitic phases including: modal proportions of quartz-alkali feldspar-plagioclase (e.g. QAP from Streckeisen, 1976); modal amounts of mafic minerals (i.e. biotite, cordierite, garnet) and muscovite; texture (e.g. megacrystic, seriate, equigranular, porphyritic, aplitic, pegmatitic, etc); and grain size (i.e. fine, medium, coarse and very coarse). Application of this classification scheme resulted in the establishment of seven main rock types in the batholith including (in decreasing order of mafic mineral content): mafic porphyry; biotite granodiorite; biotite monzogranite; muscovite-biotite monzogranite; coarse-grained leucomonzogranite; fine-grained leucomonzogranite; and muscovite leucogranite. This scheme now provides a framework for mapping granitic bodies elsewhere in the Meguma Zone, in fact it has recently been used to map the Musquodoboit Batholith (Ham, 1994).

Geological mapping defined 260 intrusive bodies that were grouped into 49 map units based upon similar texture, composition and field relations. Each map unit was assigned a geographical location and one of the seven rock types (e.g. the East Kemptville leucogranite).



When more than one rock type was present in a single unit (e.g. minor granodiorite in some biotite monzogranite units), the predominant rock type was used and the occurrence of other rock types was noted in the map legends and marginal notes. Field relationships were subsequently coupled with modal mineralogical and geochemical data, resulting in the delineation of thirteen plutons. The recognition of pluton boundaries is somewhat problematic because of similarity of ages throughout the batholith, a lack of chilling and definitive cross-cutting relationships at most major granite/granite contacts and the overall mineralogical and chemical similarities of all granitic phases.

Prior to the project, it was generally accepted that approximately 75 % of the batholith was comprised of an "envelope" of granodiorite that hosted later-staged monzogranite bodies (McKenzie and Clarke, 1975; Smith, 1979). Although previous mapping resulted in only a few local-scale divisions of the "envelope" rocks (Smitheringale, 1973; McKenzie, 1974), geological mapping and modal mineralogical evaluations revealed that this "envelope" is, in fact, comprised of biotite monzogranite with subordinate granodiorite (52.2 % versus 9.6 %, respectively). Perhaps more significantly, five discrete Stage I plutons were delineated within the previously homogeneous "envelope". Point counting and follow-up geochemical investigations indicated that four of the five Stage II plutons are normally and/or reversely zoned.

Field work revealed a systematic sequence of emplacement beginning with the intrusion of the Stage I plutons which was followed by a series of eight monzogranite - leucomonzogranite - leucogranite Stage II plutons. Contacts between the Stage I and II plutons are intrusive except for the Halifax pluton where a gradational contact is locally developed with surrounding biotite monzogranite (separate pluton?). The coarse-grained, commonly megacrystic units (predominantly leucomonzogranite and muscovite-biotite monzogranite with subordinate biotite monzogranite and biotite granodiorite) of the Stage II plutons were the first rocks to crystallize. The contacts between these map units were observed to be both intrusive and gradational. The fine-grained leucomonzogranite and leucogranite units were the last rocks to be emplaced in the batholith. Contacts with coarse-grained megacrystic units were predominantly intrusive with the exception of a few fine-grained leucomonzogranite bodies, mainly in the New Ross pluton, where gradational contacts indicate they represent textural equivalents of the coarse-grained

leucomonzogranite rocks (Corey, 1988a).

Several field observations indicate that the above sequence of emplacement of granitic rocks may be somewhat simplistic including: the presence of leucomonzogranite xenoliths in biotite monzogranite and biotite granodiorite units indicates that the granodiorite from some Stage I plutons post-dated the crystallization of some leucomonzogranite, although the unequivocal origin of these enclaves has not been established (i.e. could be from high-grade metamorphic regions below current level of erosion); the presence of 'late' intrusive bodies cutting more-evolved rocks (e.g. portions of the Tantallon leucomonzogranite in the Halifax Pluton are less evolved than their coarse-grained leucomonzogranite host rocks (MacDonald and Horne, 1988)); the complex sequence of emplacement of granodiorite - coarse-grained leucomonzogranite - aplite near Sambro in the Halifax Pluton that was described in Chapter 6; the complex layered sequence at Chebucto Head (Chapter 6) that suggests intrusion of crystal mush into fractures in crystallized monzogranite; the large compositional range shown by aplite dykes in a single outcrop of Sandy Lake biotite monzogranite along the margin of the Halifax Pluton (see details and discussions in Chapters 3, 4 and 5). Although some of these features can be explained by more than one process, collectively they infer a somewhat complex sequence of emplacement for the granitic rocks of the batholith.

Detailed petrographic studies of the six main rock types (i.e. excluding mafic porphyry) indicate that rocks of the various plutons have similar mineralogical characteristics. For example, the presence of biotite, muscovite, aluminosilicate (e.g. andalusite), cordierite, garnet and tourmaline, in virtually all of the plutons, is consistent with the "characteristic" mineral assemblage for peraluminous granites as defined by Clarke (1981). This same mineral assemblage, in particular the abundance of cordierite (up to 5%), combined with the absence of hornblende and titanite is consistent with "S-type" granitoids as described by Chappell and White (1974) and White et al. (1986). The only occurrence of magnetite in the entire batholith is in a single sample of albite-magnetite breccia from a drill hole near the East Kemptville deposit (Richardson, 1988) where the presence of intense alteration and deformation suggests a post-magmatic origin for the assemblage. The ubiquitous occurrence of accessory ilmenite, along with muscovite and low Mg/Fe biotite, is consistent with the "ilmenite-series" granitoids as described by Ishihara (1977).

Detailed chemical studies demonstrate that the rocks of the batholith have similar overall chemical characteristics with  $A/CNK > 1$ , high levels of  $SiO_2$  and low levels of  $CaO$ . Major and trace element chemistry and normative compositions define a continuous sequence from least evolved granodiorite to most evolved leucogranite. This sequence is interpreted as representing fractional crystallization with the progressive removal of plagioclase, K-feldspar and inclusion-rich biotite (zircon, monazite, apatite, ilmenite) in the various plutons, as previously proposed by McKenzie and Clarke (1975), Smith (1979), MacDonald and Horne (1988) and MacDonald et al. (1992), to explain compositional variations within portions of the batholith. The recent discovery of a plagioclase-rich cumulate phase in the Big Indian Lake pluton (Corey and Chatterjee, 1992) also supports the fractional crystallization model for the batholith. Deflections in chemical trends (Figs. 5.3a to h), and drastic increases in standard deviations for several "incompatible" trace elements in leucogranitic units are interpreted as reflecting fluid/melt and/or fluid/rock processes as suggested by Kontak et al. (1988) and MacDonald and Clarke (1991).

Despite overall compositional similarities, detailed geochemical and mineralogical studies (Horne et al., 1989; MacDonald et al., 1992; data in this report) has revealed slight, but significant, variations in the mineralogy and geochemistry of the various plutons. In fact, similar rock units (e.g. biotite monzogranite, coarse-grained leucomonzogranite) from different plutons have successfully been discriminated using multi-variate statistical techniques. One explanation for these compositional variations is that varying physico-chemical conditions prevailed during crystallization of the sundry plutons. However, the suite of elements used in the multi-variate discriminate function analysis was entirely high field strength elements that reside primarily in biotite and its inclusions. MacDonald and Clarke (1991) have established that these elements are the least effected by late- and post-magmatic processes, that is, the processes that would be most likely to vary with changing physico-chemical conditions. In fact, the distribution of these elements is strongly controlled by the bulk composition of the melt and the respective distribution coefficients. Therefore, an alternate explanation is favoured in which the slight compositional differences are manifestations of chemical heterogeneities in the protoliths that were melted to form the thirteen plutons. Based upon physical constraints for the emplacement of magmas in the batholith, Horne et al. (1992) concluded that the various plutons were generated by melting of

crustal rocks approximately beneath their present location. Therefore, it is reasonable to expect regional changes in protolith composition.

The South Mountain Batholith is, in general terms, massive and lacks the penetrative structural deformation that is characteristic of syn-tectonic or syn-kinematic granitoid bodies. Accordingly, it is interpreted to have been emplaced after the regional deformation associated with the Middle Devonian Acadian Orogeny. However, it is evident from the structural data that the batholith was subject to regional stresses during, and subsequent to, emplacement and crystallization. Horne et al. (1988, 1992) concluded that the planar features (i.e. joints, dykes, veins, faults and shear zones) developed during northwest, horizontal compression accompanying uplift during the waning stages of the Acadian Orogenic event.

Some faults are interpreted to have been active prior to and following the emplacement and crystallization of Stage I and II plutons. Some Stage II plutons are localized along major faults and shear zones (e.g. the East Dalhousie Pluton and part of the Davis Lake Pluton) and may in fact be deformed from further movement along these faults. These structures are therefore interpreted to have played an important role in the emplacement of the batholith. Initial geochronological data indicates that some faults were active for long time periods during and subsequent to the batholith emplacement. For example, Kontak et al. (1989) and Kontak and Cormier (1991) concluded on the basis of geochronological data, that the East Kemptville-East Dalhousie Fault Zone was episodically active from ca. 350 to 250 Ma.

The presence of sharp intrusive granite/country rock contacts, abundant metasedimentary xenoliths in biotite-rich granitic units and the general lack of deformation in country rocks indicates that the bulk of the batholith was emplaced by a passive stoping mechanism. However, evidence for local-scale deformation of the country rocks was noted near Hammonds Plains north of Halifax (Faribault, 1908; MacDonald and Horne, 1987), on the Aspotogan Peninsula (O'Brien, 1988), in Halifax city (Clarke and Halliday, 1980) and possibly along the northwestern margin of the batholith north of East Kemptville (Horne et al., 1992).

Estimates for the depth of emplacement of the batholith are for the most part poorly constrained with approximated pressures of crystallization ranging from 2-4 kb, based principally on phase equilibria for various AFM mineral phases. Recent work by Mahoney (1996) estimates

the pressures for metamorphic reactions in the thermal aureole around the batholith at 250 MPa in the western regions to 400 MPa near the eastern margin. These pressures correspond to depths of 6 km and 10 km depth for the western and eastern parts of the batholith respectively.

Three opposing models for the origin and emplacement of the South Mountain Batholith have been advanced. First, McKenzie and Clarke (1975), Charest et al. (1985) and Clarke and Muecke (1985) have proposed that the entire batholith represents a single co-magmatic body that fractionated in-situ (?). Conversely, Smith and Turek (1976) and Smith (1979) suggested that batholith was emplaced as a series of discrete plutons that subsequently coalesced to form a composite batholith. In both instances, the entire batholith was assumed to have crystallized ca. 360-370 Ma. Lastly, Richardson et al. (1989) concluded that the Davis Lake pluton was intruded approximately 30 to 40 Ma after the main "cogenetic" South Mountain Batholith. She concluded that the Davis Lake pluton was generated by remelting of the residue from the first melting event that generated the rest of the batholith. The results from this project have substantially refined the original geological map of the batholith and provide new insight into its intrusion and crystallization history.

There is overwhelming geochronological evidence that the entire batholith was emplaced during a very narrow time interval ca. 370 Ma (Chapter 7) despite the definitive emplacement sequence observed during geological mapping. This restricted time interval for emplacement of the batholith predicates the generation of massive amounts of granitic magma pre-370 Ma. As previously discussed, detailed petrographic, geochemical and isotopic studies of xenoliths from a mafic dyke near Tangier (Eberz et al., 1988, 1991) indicate that upper crustal rocks, possibly from the Avalon Terrane, were subducted beneath the Meguma Terrane during the continent/continent collision related to the Acadian Orogeny. The subjection of upper crustal rocks to lower crustal P-T conditions would necessitate melting and the generation of peraluminous, felsic magma. In addition, the presence of ca. 370 Ma mantle-derived mafic intrusions in the Liscomb Complex (Chatterjee and Giles, 1988; Kontak et al., 1989) suggests that underplating of the Tangier-Liscomb area by mantle magma also occurred. Therefore, the massive amounts of granitic magma required to form the composite South Mountain Batholith may be explained by similar processes evoked (Eberz et al., 1991; Clarke et al., in press) to explain the genesis of the



Tangier granulite xenoliths, the Liscomb gneisses and the nearby granites.

### 11.2 Economic Geology of the Batholith

Mineral exploration has lead to the discovery of: numerous polymetallic Sn-W-U-Mo style occurrences throughout the batholith; the former New Ross manganese mines; the East Kemptville Sn-Cu-Zn-Ag deposit; and the Millet Brook U-Cu-Ag deposit. All deposits can be classified into five main types. These include greisen, vein, breccia, pegmatite and peribatholithic deposit types. The first four types are defined on the basis of their mineralogy, attending alteration assemblages and field relations. In contrast, peribatholithic deposits are defined only on the basis of field relations and may represent mineralization types similar to the first four categories.

To date, only greisen- and vein-type deposits have proven to be economically viable. The potential for additional deposits of these types is considered excellent. A project designed to evaluate the potential of breccia-type deposits in the Little Tobeatic Lake area was conducted as part of the 1993-96 Canada - Nova Scotia Cooperation Agreement on Mineral Development (Corey and Graves, 1993). Pegmatite-type deposits within the batholith are generally considered to have a low economic potential; however, the spodumene (Li)- and tourmaline-bearing Brazil Lake pegmatite may have potential as a source for industrial minerals (e.g. spodumene, feldspar) or gem quality minerals (e.g. blue tourmaline). The potential for peribatholithic deposits similar to the Duck Pond deposit and Caledonia occurrences is considered to be very high, particularly in the Southwest Nova Scotia Tin Domain, and merits future exploration.

There are several factors that contribute to the deposition and distribution of economic mineral deposits/occurrences in, and adjacent to, the batholith. These include:

- 1) The composition of granitic rocks. Clearly, as discussed in Chapter 9, the composition and degree of fractionation of granitic rocks has been interpreted to play an integral role in the generation of polymetallic Sn-W-U-Mo type mineral deposits in peraluminous granites worldwide. This feature also applies in the batholith where highly fractionated muscovite  $\pm$  topaz leucogranites are spatially, and arguably genetically, related to many of the known mineral deposits including those at East Kemptville, Millet Brook and Long Lake.

- 2) It is apparent from the discussions in Chapters 6 and 9 that structure has played an important part in the formation of mineralization in the batholith. Most vein-type mineralization

(both U-Cu-Ag and Mn-Fe styles) are associated with northeast-trending fault or shear zones whereas polymetallic greisen-type mineralization is commonly associated with northwest-trending quartz veins. In contrast, Halter et al. (1994) noted that the cassiterite-bearing greisen veins in the East Kemptville deposit, the largest known greisen-type deposit in the batholith, are northeast-southwest trending. Their work indicated that northeast-trending fractures "controlled the location of tin mineralization by providing a path for mineralizing fluids". Breccia-type mineralization, such as along the southeastern margin of the Davis Lake Pluton, has been interpreted by Corey and Graves (1993) to have formed by multiple and superimposed periods of brecciation and silicification along a major fault zone. Structure is not considered to have played a key role in the formation of pegmatite-type mineralization.

3) Many greisen-style mineral deposits, including the East Kemptville deposit, are proximal to granite/granite and granite/metasediment contacts. Presumably, these contact zones acted as either physical or chemical 'traps' for hydrothermal fluids. Chatterjee and Strong (1985) and Kontak et al. (1988) established the involvement of external fluids (metamorphic and meteoric) for several mineral deposits, based on  $\delta O^{18}$  data. Proximity to contact zones does not appear to have been an important factor in the formation and distribution of breccia-, vein- or pegmatite-type mineral deposits.

4) Chatterjee (1983) proposed a series of metallogenic domains within the batholith based on the styles and elemental assemblages of all known mineral occurrences. MacDonald *et al.* (1992b) and MacDonald (1994) concluded that many of the domains of Chatterjee (1983) occur within one or more plutons with several domain boundaries corresponding to pluton margins. This observation implies that individual plutons are directly responsible for their respective deposit types and associated suites of elements, presumably through prolonged crystal fractionation. Differences in the polymetallic character of the various domains probably reflect variations in bulk composition and physico-chemical conditions during emplacement and crystallization, and possibly varying amounts of crustal contamination during emplacement, within the various plutons of the batholith. If so, the economic mineral potential of each pluton should be considered individually, as suggested by Smith and Turek (1976).

Peribatholithic occurrences, as in the southeastern Nova Scotia tin domain and near

Caledonia, presumably represent mineralization associated with buried cupolas, much like the partially unroofed Carnubian Batholith of Cornwall, and possibly the Lake George Sb-W-Mo deposit (Seal et al., 1988) and Mount Pleasant W-Sn-Mo deposit (Taylor et al., 1985) that are both proximal to the Saint George Batholith of central New Brunswick. In fact the presence of peribatholithic mineralization is consistent with worldwide studies of the distribution of Sn mineralization where a large proportion of known mineral deposits are hosted by country rocks proximal to peraluminous granitic batholiths.

Mineral exploration in the past several decades has focused principally on the potential for greisen- and vein-type mineralization throughout the batholith with sporadic exploration for breccia-type metal deposits along the southern margin of the Davis Lake Pluton (see discussion in Chapter 9). This activity has led to the discovery of the greisen-style polymetallic-Sn deposit at East Kemptville, the vein-type U-Cu-Ag deposit at Millet Brook, and numerous other occurrences. Most mineral occurrences have been noted to have definitive geochemical and geophysical responses. The geochemical 'signatures' of the four main deposit types have been noted to reflect their different mineralogy and associated alteration mineral assemblages, subsequently, future geochemical programmes should consider utilizing statistical techniques to establish multi-element anomalies. This procedure may assist in differentiating between styles of mineralization, for example, it may be possible to distinguish F anomalies associated with vein-type mineralization (U-Cu-Mn-P-F-Ag) from greisen (Sn-W-Mo-As-Cu-Pb-Zn-Bi-Au-Ag-B-F-P-Na-K) or pegmatite (Mo-Sn-W-Cu-Nb-Ta-Be-B-F) by looking at the associated elemental assemblages. An evaluation of government and private-industry activities reveals that mineral exploration for granite-hosted mineral deposits can use several geochemical techniques (e.g. lake, till, plant-tissue and humus sample media) and geophysical techniques (e.g. Gamma-Ray Spectrometry, Very Low Frequency (VLF); Electromagnetic (EM), Induced Polarization (IP) and Resistivity surveys) to explore for additional mineral deposits.

### 11.3 Conclusions

Several important conclusions can be drawn from the results of the South Mountain Batholith project:

- 1) Geological mapping of the South Mountain Batholith of southwestern Nova Scotia was

conducted as part of the 1984-1989 Canada-Nova Scotia Mineral Development Agreement. A rock classification scheme was developed for subdividing granitic rocks. The scheme combined the relative proportions of quartz-alkali feldspar-plagioclase, modal proportions of biotite ( $\pm$ cordierite $\pm$ garnet) and muscovite, grain size and texture. Seven main rock types were established using this scheme, including (in decreasing order of mafic mineral content): mafic porphyry, biotite granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite and muscovite $\pm$ topaz leucogranite.

2) Geological mapping, coupled with detailed point counting rock slabs, indicates the amount of granodiorite in the batholith is approximately 9.6% compared with previous estimates of up to 75%. The most abundant rock type in the batholith is biotite monzogranite which is the dominant rock type in Stage I plutons and accounts for 52.2% of the total area of the batholith.

3) A total of 260 discrete granite map bodies were delineated in the batholith. These bodies were grouped into 49 map units based on field relationships and composition. Each map unit was assigned a prominent place name or geographical feature and a rock name (e.g. East Kemptville leucogranite).

4) The 49 map units were assigned to 13 plutons, based on field relationships and compositional variations. Five plutons are classed as early Stage I, comprising biotite granodiorite and biotite monzogranite with minor fine-grained leucomonzogranite. These were the first plutons to be emplaced. Stage I plutons were intruded by a series of eight Stage II plutons, comprising muscovite-biotite monzogranite, coarse- and fine-grained leucomonzogranite and muscovite leucogranite with minor biotite granodiorite and biotite monzogranite.

5) Contacts between Stage I and II plutons are not well exposed but, where observed, are primarily intrusive. Contacts between the coarser grained megacrystic units in Stage II plutons are mainly intrusive, but some were noted to be gradational. Contacts between biotite monzogranite and biotite granodiorite in Stage I plutons were noted to be both intrusive and gradational. Late-staged fine-grained leucomonzogranite and leucogranite mainly intrude the megacrystic units with the exception of a few porphyry bodies in the New Ross Pluton that are in gradational contact with the megacrystic leucomonzogranite and represent textural variations of the host.

6) Detailed petrographic studies of the six main rock types indicate that rocks of the

various plutons have similar mineralogical characteristics. For example, the presence of biotite, muscovite, aluminosilicate (e.g. andalusite), cordierite, garnet and tourmaline, in virtually all of the plutons, is consistent with the "characteristic" mineral assemblage for peraluminous granites. Hornblende has not been observed in any of the rocks of the batholith. The only occurrence of magnetite in the entire batholith is in a single hydrothermally altered sample of albite-magnetite breccia from a drill hole near the East Kemptville deposit. The ubiquitous occurrence of accessory ilmenite, along with muscovite and low Mg/Fe biotite, is consistent with the "ilmenite-series" granitoids.

7) Detailed investigations indicate that although most major rock-forming mineral phases are of magmatic origin, many minerals also formed by xenocrystic, hyperaluminous or metasomatic processes at various stages in the evolution of the batholith. Therefore the exact origin of a mineral phase in any given rock must be evaluated individually to establish its origin.

8) Despite overall textural and mineralogical similarities throughout the batholith, several plutons display unique petrographic features. These mineralogical features suggest that different physico-chemical conditions ( $T$ ,  $P_{H_2O}$ ,  $fO_2$ , bulk composition) prevailed in the various plutons.

9) Lithogeochemical analysis of a suite of 597 samples, representing the complete compositional range for the batholith, were analyzed for major elements and a suite of 21 trace elements. Perhaps the most striking feature of the geochemistry of the batholith is the overall similarity in composition throughout the batholith. All rocks are peraluminous (i.e. molecular  $Al_2O_3/(CaO+K_2O+Na_2O) > 1$ ) and have relatively high  $SiO_2$  and low  $CaO$  with ranges from 67.12% (SD-1.73) and 1.94% (SD-0.46), respectively, in granodiorite to 73.62% (SD-0.89) and 0.39 (SD-0.14), respectively, in leucogranite rocks.

10) The major element chemistry and normative composition of the major rock types indicates a sequence from least evolved biotite granodiorite to most evolved leucogranite that reflects the petrographic features of the different rock types. This sequence is marked by systematic decreases in  $TiO_2$ ,  $Fe_2O_3$ ,  $MnO$ ,  $MgO$ ,  $CaO$ ,  $K/Rb$  and normative anorthite, enstatite, ilmenite, hematite, rutile and colour index and increases in  $SiO_2$ , normative quartz,  $A/CNK$  and Thornton-Tuttle differentiation index. The concentration of  $P_2O_5$  is generally consistent from granodiorite to fine-grained leucomonzogranite with a sharp/abrupt increase in leucogranite units.



This sequence is also marked by systematic decreases in several compatible trace elements (i.e. Ba, Sr, Zr, V, Hf, Sc and La) and increases in several incompatible trace elements (i.e. Rb, Ta, U, Li, F, Sn and W).

11) It is possible to distinguish among individual plutons, despite the overall compositional similarities throughout the batholith, thus indicating that the batholith constitutes numerous discrete plutons that coalesced to form a contiguous batholith, in contrast to earlier studies that proposed the entire batholith formed from a single parental magma.

12) Perhaps one of the most important implications of the geochemical data is the delineation of cryptic normal and reverse compositional zoning in both Stage I and II plutons. Zoning is interpreted to have been formed by *in-situ* fractional crystallization, although the contribution from sidewall fractionation or formation of cumulates cannot be ruled out.

13) In spite of a definitive sequence of emplacement for the plutons and their units, an evaluation of published geochronological data indicates that all plutons were intruded and crystallized during a very short time interval ( $< 5$  Ma) at ca. 370 Ma.

14) Structural characteristics, including the shape and distribution of plutons, the coincidence of several Stage II plutons with major fault zones, and the orientation of primary and secondary structural features (e.g. megacryst alignment, joints, veins), indicate that the batholith was subject to regional stresses associated with the waning stages of the Acadian Orogeny.

15) Mineral occurrences can be classed into 4 types including: greisen-type (e.g. East Kemptville); vein-type (e.g. New Ross Mn Mines; Millet Brook); breccia-type (e.g. Tobeatic Shear Zone); pegmatite-type (e.g. several occurrences in the New Ross Pluton; and peribatholithic (e.g. the Duck Pond Sn deposit). Similarly, the style of mineralization in the sundry plutons is interpreted as reflecting the protolith composition and the physico-chemical conditions that prevailed during their crystallization. Accordingly, the economic potential of the 13 plutons must be evaluated individually.

## *References*

- ABBOTT, R.N. Jr. 1989. Internal structures in part of the South Mountain Batholith, Nova Scotia, Canada. *Geological Society of America Bulletin*, 101, pp. 1493-1506.
- ALLAN, B.D and CLARKE, D.B., 1981. Occurrence and origin of garnets in the South Mountain Batholith, Nova Scotia. *Canadian Mineralogist*, 19, pp. 19-24.
- BATEMAN, P.C. 1988. Constitution and genesis of the Central Part of the Sierra Nevada Batholith, California. *United States Geological Survey Open File Report 88-382*, 188 p.
- BATES, J.L. 1987. Gold in Nova Scotia. Nova Scotia Department of Mines and Energy, Information Series No. 13, 48 pp.
- BELL, K. and BLENKINSOP, J. 1960. Mississippian Horton Group of type Windsor-Horton district, Nova Scotia; Geological Survey of Canada, Memoir 314, 112 p.
- BINGLEY, J.M. and RICHARDSON, G.G. 1978. Regional lake sediment surveys for eastern mainland Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 371, 39 maps, scale 1:100,000.
- BOEHNER, R.C. and GILES, P.S. 1993. Geology of the Antigonish Basin, Antigonish County, Nova Scotia. Nova Scotia Department of Natural Resources, Mines and Energy Branches, Memoir 8, 109 p.
- BONER, F.J., FINCK, P.W. and GRAVES, R.M. 1990. Trace element analysis of till (-230 mesh), South Mountain Batholith. Nova Scotia Department of Mines and Energy, Open File Report 90-006.
- BOUCOT, A.J. 1960. Implications of Rhenish Lower Devonian brachiopods from Nova Scotia. *International Geological Congress Report of the Twenty-First Session*, 12, pp. 129-137.
- BOYLE, R.W., KOEHLER, G.F., MOXHAM, R.L. and PALMER, H.C. 1958. Heavy metal (Zn, Cu, Pb) content of water and sediments in the streams, rivers and lakes of southwestern Nova Scotia; Geological Survey of Canada, Paper 58-1.
- BROOKS, R.R., HOLZBECHER, J., ROBERTSON, D.J. and RYAN, D.E. 1982. Biogeochemical prospecting for Uranium in Nova Scotia. *Journal of Geochemical Exploration*, 16, pp. 189-195.
- BUDDINGTON, A.F. 1959. Granite emplacement with special reference to North America. *Bulletin Geological Society of America*, 70, pp. 671-747.
- CHAPPELL, B.W. and WHITE, A.J.R. 1974. Two contrasting granite types. *Pacific Geology*, 8, pp. 173-174.
- CHAREST, M.H. 1976. Petrology, geochemistry and mineralization of the New Ross area, Lunenburg County, Nova Scotia. Unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 154 p.
- CHAREST, M.H., FARLEY, E.J. and CLARKE, D.B. 1985. The northwestern part of the New Ross-Vaughan Complex: petrology, geochemistry and mineral deposits. *in* A.K. Chatterjee and D.B. Clarke (eds.). *Guide to the Granites and Mineral Deposits of Southwestern Nova Scotia*. Nova Scotia Department of Mines and Energy, Paper 85-3, pp. 29-40.
- CHATTERJEE, A.K. 1980. Maritime Mineral Exploration Discussion Group, Annual Meeting, Truro, Nova Scotia; Internal Report, 19 p.

CHATTERJEE, A.K. 1983. Metallogenic map of Nova Scotia. Nova Scotia Department of Mines and Energy map, scale 1:500,000.

CHATTERJEE, A.K. and CORMIER, R.F. 1991. A Rb/Sr geochronological study of the Davis Lake pluton, South Mountain Batholith, southern Nova Scotia: Evidence for 375 Ma time of emplacement. Nova Scotia Department of Mines and Energy, Report 91-5.

CHATTERJEE, A.K. and GILES, P.S. 1988. Meguma Zone basement II: P-T evolution of granulite xenoliths (abstract). Geological Association of Canada-Mineralogical Association of Canada Joint Annual Meeting. Program with Abstracts, 13, p. A19.

CHATTERJEE, A.K. and HAM, L.J. 1991. U-Th-Pb systematics of the South Mountain Batholith, Nova Scotia. In Atlantic Geoscience Society Annual Colloquium, Proceedings with Abstracts, Sackville, New Brunswick.

CHATTERJEE, A.K. and HORNE, R.J. 1991. Variations in LIL elements, HFS elements and REE within the Davis Lake pluton, southwestern Nova Scotia. In Atlantic Geoscience Society Annual Colloquium, Proceedings with Abstracts, Sackville, New Brunswick.

CHATTERJEE, A.K. and MacDONALD, M.A. 1991. Contrasting greisens and associated granitoid rocks of the Davis Lake pluton: Implications for the origin of the East Kemptville tin deposit, Nova Scotia. in Atlantic Geoscience Society Annual Colloquium, Proceedings with Abstracts, Sackville, New Brunswick.

CHATTERJEE, A.K. and MUECKE, G.K. 1982. Geochemistry and the distribution of uranium and thorium in the granitic rocks of the South Mountain Batholith, Nova Scotia: some genetic and exploration implications; In Uranium in Granites. Edited by Y.T. Maurice, Geological Survey of Canada, Paper 81-23, pp. 11-17.

CHATTERJEE, A.K., ROBERTSON, J. and POLLOCK, D. 1982. A summary on the petrometallogenesis of the uranium mineralization at Millet Brook, South Mountain Batholith, Nova Scotia. Nova Scotia Department of Mines and Energy Report 82-1, pp. 57-67.

CHATTERJEE, A.K. and STRONG, D.F. 1984a. Discriminant and factor analysis of geochemical data from granitoid rocks hosting the Millet Brook uranium mineralization, South Mountain Batholith, Nova Scotia. Uranium 1, pp. 289-305.

CHATTERJEE, A.K. and STRONG, D.F. 1984b. Rare-earth and other element variations in greisens and granites associated with East Kemptville tin deposit, Nova Scotia, Canada. Transactions of the Institute of Mining and Metallurgy, 93, p. B59-70.

CHATTERJEE, A.K. and STRONG, D.F. 1985. Geochemical characteristics of the polymetallic tin domain southwestern Nova Scotia, Canada (Extended Abstract). In R.P. Taylor and D.F. Strong (eds.). Granite-Related Mineral Deposits - Geology, Petrogenesis and Tectonic Setting. Canadian Institute of Mining, pp. 41-52.

CHATTERJEE, A.K., STRONG, D.F., CLARKE, D.B., ROBERTSON, J., POLLOCK, D. and MUECKE, G.K. 1985. Geochemistry of the granodiorite hosting uranium mineralization at Millet Brook. in A.K. Chatterjee and D.B. Clarke (eds.). Guide to the Granites and Mineral Deposits of Southwestern Nova Scotia. Nova Scotia Department of Mines and Energy, Paper 85-3, pp. 63-114.

CHORLTON, L.B. and MARTIN, R.F. 1978 The effect of boron on the granite solidus. Canadian Mineralogist, 16, pp. 239-244.

- CLARKE, D.B. 1981. The mineralogy of peraluminous granites: a review. *Canadian Mineralogist*, 19, pp. 3-17.
- \_\_\_\_\_. 1992. *Granitoid Rocks*. Chapman and Hall, London, Glasgow, New York, Tokyo, Melbourne, Madras. 283 p.
- CLARKE, D.B. and CHATTERJEE, A.K. 1988. Physical and chemical processes in the South Mountain Batholith. In R.P. Taylor and D.F. Strong (eds.), *Recent Advances in the Geology of Granite-Related Mineral Deposits*. Canadian Institute of Mining and Metallurgy, Special Volume 39, pp. 223-233.
- CLARKE, D.B., CHATTERJEE, A.K. and GILES, P.S. 1993. Petrochemistry, tectonic history, and Sr-Nd systematics of the Liscomb Complex, Meguma Lithotectonic Zone, Nova Scotia. *Canadian Journal of Earth Sciences*, 30, pp.449-464.
- CLARKE, D.B. and HALLIDAY, A.N. 1980. Strontium isotope geology of the South Mountain Batholith, Nova Scotia. *Geochimica et Cosmochimica Acta*, 44, pp. 1045-1058.
- \_\_\_\_\_. 1985. Sm/Nd isotopic investigation of the age and origin of the Meguma Zone metasedimentary rocks. *Canadian Journal of Earth Sciences*, 22, pp. 102-107.
- \_\_\_\_\_. 1988. Neodymium and strontium isotopic constraints on the origin of the peraluminous granitoids of the South Mountain Batholith, Nova Scotia, Canada. *Chemical Geology (Isotope Geoscience Section)*, 73, pp. 15-24.
- CLARKE, D.B., MacDONALD, M.A., REYNOLDS, P.H. and LONGSTAFFE, F.J. (1993). Leucogranites from the eastern part of the South Mountain Batholith, Nova Scotia. *Journal of Petrology*, 34 pp. 653-679.
- CLARKE, D.B., McKENZIE, C.B., MUECKE, G.K. and RICHARDSON, S.W. 1976. Magmatic andalusite from the South Mountain Batholith, Nova Scotia. *Contributions to Mineralogy and Petrology*, 56, pp. 279-287.
- CLARKE, D.B. and MUECKE, G.K. 1980. Igneous and metamorphic geology of Nova Scotia. Geological Association of Canada-Mineralogical Association of Canada, Field Trip Guidebook, 21, 101 p.
- CLARKE, D.B. and MUECKE, G.K. 1985. Review of the petrochemistry and origin of the South Mountain Batholith and associated plutons, Nova Scotia, Canada. In *High Heat Production (HHP) Granites, Hydrothermal Circulation and Ore Genesis*. Institution of Mining and Metallurgy, England, pp. 41-54.
- COBBING, E.J., PITCHER, W.S., WILSON, J.J., BALDOCK, J.W., TAYLOR, W.P., McCOURT, W. and SNELLING, N.J. 1981. The geology of the western Cordillera of northern Peru. Institute of Geological Sciences, Overseas Memoir 5, 143 p.
- COREY, M.C. 1983. Report on the field work 1982, Whale Lake Claims, Lunenburg County; Kidd Creek Mines Ltd. Nova Scotia Department of Mines and Energy, Assessment report 21A/10A 51-L-54(01).
- COREY, M.C. 1987. Bedrock geological map of Mount Uniacke, NTS sheet 11D/13 (west half). Nova Scotia Department of Mines and Energy, Map 87-8, scale 1:50,000.
- \_\_\_\_\_. 1988a. Preliminary geological map of Chester, NTS sheet 21A/09. Nova Scotia Department of Mines and Energy, Open File Map 88-013, scale 1:50,000.
- \_\_\_\_\_. 1988b. An occurrence of metasomatic aluminosilicates related to high alumina hydrothermal alteration within the South Mountain Batholith. *Maritime Sediments and Atlantic Geology*, 24, pp. 83-96.

\_\_\_\_\_. 1990. Geological map of Chester, NTS sheet 21A/09. Nova Scotia Department of Mines and Energy Map 90-09, scale 1:50 000.

\_\_\_\_\_. 1992. Geological features within the Big Indian Lake pluton, Hants County, Nova Scotia: Evidence of igneous layering from recent diamond drilling. *Atlantic Geology* 28, pp. 51-62.

\_\_\_\_\_. 1994. Diamond-drilling of rare element pegmatites in southwestern Nova Scotia; *in* Mines and Minerals Branch, Report of Activities 1993, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report 94-01, pp. 65-79.

COREY, M.C. and CHATTERJEE, A.K. 1992. Geochemistry of peraluminous, plagioclase-rich cumulate and associated granitic rocks from the Big Indian Lake Pluton, Nova Scotia (abstract). Geological Association - Mineralogical Association of Canada Joint Annual Meeting. Program with Abstracts, 17, p. A20.

COREY, M.C. and CHATTERJEE, A.K. 1992. Characteristics of REE and other trace elements in response to successive and superimposed metasomatism within a portion of the South Mountain Batholith, Nova Scotia, Canada. *Chemical Geology*, 85, pp. 265-285.

COREY, M.C. and GRAVES, R.M. 1993. The occurrence and economic potential of fault- and shear-related polymetallic mineralization along the southern contact of the South Mountain Batholith. Nova Scotia Department of Natural Resources Report 93-2, pp. 21.

COREY, M.C. and HORNE, R.J. 1989a. Preliminary geological map of Lake Rossignol, NTS sheet 21A/03. Nova Scotia Department of Mines and Energy, Open File Map 89-010, scale 1:50,000.

\_\_\_\_\_. 1989b. Preliminary geological map of Milford, NTS sheet 21A/11. Nova Scotia Department of Mines and Energy, Open File Map 89-014, scale 1:50,000.

\_\_\_\_\_. 1989c. Polymetallic-precious metal potential of the Tobeatic fault zone in southwestern Nova Scotia. Nova Scotia Department of Mines and Energy Report 89-1, part B, pp. 27-36.

\_\_\_\_\_. 1994a. Geological map of Lake Rossignol, NTS sheet 21A/03. Nova Scotia Department of Natural Resources, Map 94-2, scale 1:50,000.

\_\_\_\_\_. 1994b. Geological map of Milford, NTS sheet 21A/11. Nova Scotia Department of Natural Resources, Map 94-6, scale 1:50,000.

CORMIER, C.F.M., 1988. Greisenization and metasomatism associated with Meguma-South Mountain Batholith contacts, Inglisville, Nova Scotia. unpublished B.Sc. (Hon.) thesis, Saint Francis Xavier University, Antigonish, Nova Scotia, 81 p.

CORMIER, R.F. and SMITH, T.E. 1973. Radiometric ages of granitic rocks, southwestern Nova Scotia. *Canadian Journal of Earth Sciences*, 10, pp. 1201-1210.

COWIE, J.W. and BASSETT, M.G. 1989. International Union of Geological Sciences, 1989 Global Stratigraphic Chart. *Episodes*, (Suppl.), 12(2).

DAKERS, R.W.G. 1982. Assessment Report of exploration in Annapolis and Digby Counties. Nova Scotia Department of Mines and Energy Assessment Report 434324, 70 p.



- DALLMEYER, R.D. and KEPPIE, J.D. 1987. Superposed Late Paleozoic thermal events in the southwestern Meguma Terrane, Nova Scotia. *Maritime Sediments and Atlantic Geology*, 24, pp. 157-169.
- DEBON, F. and LEFORT, P.Le. 1983. A chemical-mineralogical classification of common plutonic rocks and associations, *Transactions of the Royal Society of Edinburgh. Earth Sciences*, 73, pp.135-149.
- DEWOLFE, V. C. 1994. Contact Relations between the New Ross Leucomonzogranite and the Falls Lake Mafic Porphyry: Evidence for Magma - Magma Interactions in the South Mountain Batholith. Unpublished B. Sc. Honours thesis, Dalhousie University, Halifax. 93 p.
- DICKIE, G.B. 1983. Report on geological, rock geochemical, ground magnetic, ground gravity, ground VLF and IP/Resistivity surveys, tin, Caledonia, Queens County, Nova Scotia. Nova Scotia Department of Mines and Energy Assessment Report 21A/06A 51-N-06(05), 20 p.
- DICKIE, G.B. and JENSEN L.R. 1981. Report of exploration, 1980, Torbrook Project. Nova Scotia Department of Mines and Energy Assessment Report 434141, 23 p.
- DICKIE, G.B. and ZWICKER, E.J. 1983. Report on geological, till, rock and IP-resistivity surveys, Bald Mountain, Shelburne County, Nova Scotia. Biliton Canada Limited. Nova Scotia Department of Mines and Energy, Assessment Report 21A/03C 54-p-14(01).
- DOUGLAS, G.V. and CAMPBELL, C.O. 1942. New Ross area, Nova Scotia Department of Mines, Annual Report on Mines, 1941. pp. 101-112.
- DUNN, C.E., BANVILLE, R.M.P. and ADCOCK, S.W. 1989. Reconnaissance biogeochemical survey, Eastern Nova Scotia. Geological Survey of Canada Open File 2002.
- DUNN, C.E., ADCOCK, S.W. and SPIRITO, W.A. 1992. Reconnaissance biogeochemical survey southwestern Nova Scotia, Part 1 - Red Spruce bark, Parts of NTS 200.P, 21A.B. Geological Survey of Canada, Open File Report 2556, 36 p.
- EBERZ, G.W., CLARKE, D.B., CHATTERJEE, A.K. AND GILES P.S. 1988. Meguma Zone basement III: geochemistry of lower crustal xenoliths (abstract). Geological and Mineralogical Association of Canada Annual Meeting, Program with Abstracts, 13, p. A35.
- \_\_\_\_\_. 1991. Chemical and isotopic composition of the lower crust beneath the Meguma lithotectonic zone, Nova Scotia: evidence from granulite facies xenoliths, *Contributions to Mineralogy and Petrology*, 109, pp. 69-88.
- EVANS, A.M. 1982. *Metallization Associated with Acid Magmatism*, New York, John Wiley, 385 pp.
- FAIRBAIRN, H.W., HURLEY, P.M., PINSEN, W. H. and CORMIER, R.F. 1960. Age of the granitic rocks of Nova Scotia. *Geological Society of America Bulletin*, 71, pp. 399-419.
- FAIRBAIRN, H.W., HURLEY, P.M. and PINSEN, W. H. 1964. Preliminary age study and initial  $Sr^{87}/Sr^{86}$  of Nova Scotia granitic rocks by the Rb-Sr whole rock method. *Geological Society of America Bulletin*, 75, pp. 253-258.
- FARIBAULT, E.R. 1908a. City of Halifax Sheet, Map No. 68, Geological Survey of Canada, Publication No. 1019.
- FARIBAULT, E.R. 1908b. Lunenburg County, Nova Scotia. Geological Survey of Canada, Summary Report, 1907, 78-83.

FARIBAULT, E.R. 1920. Geological mapping of Berwick and Lakeview map areas, Kings and Annapolis Counties, Nova Scotia. Geological Survey of Canada Summary Report, Part E, p. 13.

FARIBAULT, E.R. 1924. Chester Basin. Geological Survey of Canada map 87.

FARIBAULT, E.R. 1931. New Ross sheet, Map No. 87. Geological Survey of Canada, Publication No. 2259.

FARLEY, E.J. 1978. Mineralization of the Turner and Walker deposits of the South Mountain Batholith. unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

FINCK, P.W., BONER, F.J. and GRAVES, R.M. 1990a. Heavy mineral till geochemistry (Tin) of the eastern and central South Mountain Batholith. Nova Scotia Department of Mines and Energy Open File Report 90-004, 21 p. 3 maps.

FINCK, P.W., BONER, F.J. and GRAVES, R.M. 1990b. Heavy mineral till geochemistry (Tin) of the western South Mountain Batholith. Nova Scotia Department of Mines and Energy Open File Report 90-005, 41 p. 3 maps.

FINCK, P.W., GRAVES, R.M. and BONER, F.J. 1989. Progress report on the South Mountain Batholith: Pleistocene Survey; in Mines and Minerals Branch, Report of Activities 1989, Part A, eds. D.R. MacDonald and K.A. Mills. Nova Scotia Department of Mines and Energy Report 89-3, pp. 81-82.

FINCK, P.W., COREY, M.C. and GRAVES, R.M. 1988. A multi-disciplinary interpretation highlighting the mineral potential of the Bezanson Lake area, southwestern Nova Scotia, Nova Scotia Department of Mines and Energy Report 88-1, 179-194.

FINCK, P.W. and STEA, R.R. 1995. The compositional development of tills overlying the South Mountain Batholith, Nova Scotia. Nova Scotia Department of Natural Resources, Mines and Energy Branches Paper 95-1. 52 p.

FORD, K.L. 1993. Radioelement mapping of parts of the Musquodoboit Batholith and Liscomb Complex, Meguma Zone, Nova Scotia. In Mineral Deposit Studies in Nova Scotia, Volume 2. (ed.) A.L. Sangster. Geological Survey of Canada, Paper 91-9, pp. 71-111.

FORD, K.L. and BALLANTYNE, S.B. 1983. Uranium and thorium distribution patterns and lithogeochemistry of Devonian granites in the Chedabucto Bay area, Nova Scotia. In Current Research, Part A, Geological Survey of Canada, Paper 83-1A, pp. 109-119.

FORD, K.L. and O'REILLY, G.A. 1985. Airborne gamma-ray spectrometric surveys as an indicator of granophile element specialization and associated mineral deposits in the granitic rocks of the Meguma Zone of Nova Scotia. In High Heat Production (HHP) Granites, Hydrothermal circulation and ore genesis. Institution of Mining and Metallurgy, St. Austell, Cornwall, England, pp. 113-133.

FORD, K.L., HOLMAN, P.B., GRANT, J.A. and CARSON, J.M. 1992. Radioactivity maps of Nova Scotia. Atlantic Geology, 28, pp. 1-6.

FORD, K.L., MacDONALD, M.A., FINCK, P.W., BONER, F.J., HAM, L.J., HORNE, R.J., COREY, M.C. and GRAVES, R.M. 1989. Airborne gamma-ray spectrometry, and bedrock and surficial geology of the Davis Lake Pluton. Nova Scotia Department of Mines and Energy Report 89-3, pp. 169-171.

GEOLOGICAL SURVEY OF CANADA 1977. Airborne gamma-ray spectrometric maps, Annapolis Shelburne, Nova Scotia, Open File 429.

GILES, P.S. 1985. A major Post-Visean sinistral shear zone - new perspectives on Devonian and Carboniferous rocks of southern Nova Scotia. In A.K. Chatterjee and D.B. Clarke (eds.). Guide to the granites and mineral deposits of southwestern Nova Scotia. Nova Scotia Department of Mines and Energy, Paper 85-3, pp. 233-248.

GILES, P.S. and CHATTERJEE, A.K. 1984. Tin production - The tip of the iceberg in southwestern Nova Scotia. Annual meeting of the Mining Society of Nova Scotia, Ingonish, 15 pp.

\_\_\_\_\_. 1986. Peraluminous granites of the Liscomb Complex. Nova Scotia Department of Mines and Energy, Tenth Annual Open House and Review of Activities. Programs and Summaries, pp. 83-89.

\_\_\_\_\_. 1987. Lower crustal xenocrysts and xenoliths in the Tangier dyke, eastern Meguma Zone, Nova Scotia. Nova Scotia Department of Mines and Energy, Report 87-5, pp. 85-88.

GRAVES, R.M. and FINCK, P.W. 1988. The provenance of tills overlying the eastern part of the South Mountain Batholith, Nova Scotia. *Maritime Sediments and Atlantic Geology*, V. 24, pp. 61-70.

GRAVES, R.M., MacDONALD, M.A., FINCK, P.W. and BONER, F.J. 1988. A comparison of the clast composition and geochemistry of granite tills to underlying bedrock in the Halifax Pluton, central Nova Scotia. In D.R. MacDonald (Editor). *Prospecting in areas of glaciated terrain*. Canadian Institute of Mining and Metallurgy, pp. 21-40.

GROVES, D.I. and McCARTHY, T.S. 1978. Fractional crystallization and the origin of tin deposits in granitoids. *Mineralium Deposita* 13, 11-26.

HALTER, W.E., WILLIAMS-JONES, A.E. and KONTAK, D.J. 1993. Geometry and distribution of tin mineralization at East Kemptville, Yarmouth County, Nova Scotia. Nova Scotia Department of Natural Resources, Report 93-2, p. 20.

HAM, L.J. 1988. Preliminary geological map of Windsor, NTS sheets 21A/16 (west half) and part of 21H/01. Nova Scotia Department of Mines and Energy, Open File Map 88-015, scale 1:50,000.

\_\_\_\_\_. 1990. Geological map of Windsor, NTS sheets 21A/16 (west half) and part of 21H/01. Nova Scotia Department of Mines and Energy, Map 90-10, scale 1:50,000.

\_\_\_\_\_. 1989. Preliminary geological map of Digby, NTS sheet 21A/12. Nova Scotia Department of Mines and Energy, Open File Map 89-015, scale 1:50,000.

\_\_\_\_\_. 1994. Geological map of Digby, NTS sheet 21A/12. Nova Scotia Department of Natural Resources, Map 94-7, scale 1:50,000.

HAM, L.J. 1994. An update on the Musquodoboit Batholith project. Nova Scotia Department of Natural Resources, Mines and Energy Branches Report 94-1, p. 131-136.

HAM, L.J., COREY, M.C., HORNE, R.J. and MacDONALD, M.A. 1990. Lithogeochemistry of the western portion of the South Mountain Batholith, Nova Scotia. Nova Scotia Department of Mines and Energy, Open File Report 90-007, 31 p.

HAM, L.J. and HORNE, R.J. 1987. Bedrock geological map of Windsor NTS sheet 21A/16 (east half). Nova Scotia Department of Mines and Energy, Map 87-7, scale 1:50,000.

HAM, L.J. and KONTAK, D.J. 1988. A textural and chemical study of white mica in the South Mountain Batholith, Nova Scotia: primary versus secondary origin. *Atlantic Geology*, 24, pp. 111-121.

HAM, L.J. and MacDONALD, M.A. 1991. Preliminary geological map of Wentworth Lake, NTS sheet 21A/04. Nova Scotia Department of Mines and Energy, Open File Map 89-011, scale 1:50,000.

\_\_\_\_\_. 1994. Geological map of Wentworth Lake, NTS sheet 21A/04. Nova Scotia Department of Natural Resources, Map 94-3, scale 1:50,000.

HAM, L.J., MARSH, S.W., COREY, M.C., HORNE, R.J. and MacDONALD, M.A. 1989. Lithogeochemistry of the eastern portion of the South Mountain Batholith, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 89-001, 65 p.

HATTIE, K.L. 1989. Petrography and surface geology of the Duck Pond Zone sediment-hosted tin prospect, Yarmouth County, Nova Scotia. unpublished B.Sc. thesis, Mount Allison University, Sackville, New Brunswick.

HARPER, C.L. 1988. On the nature of time in the cosmological perspective. Unpublished Ph.D. thesis. Oxford University, London, England, 508 p.

HOLDAWAY, M.J. 1971. Stability of andalusite and the aluminum silicate phase diagram. *American Journal of Science* 271, pp. 97-131.

HORNE, R.J. 1987. Preliminary geology map of New Germany NTS sheet 21A/10. Nova Scotia Department of Mines and Energy, Open File Map 87-004, scale 1:50,000.

\_\_\_\_\_. 1993. Geology map of New Germany NTS sheet 21A/10. Nova Scotia Department of Natural Resources, Map 93-02, scale 1:50,000.

HORNE, R.J. and COREY, M.C. 1991. Preliminary geological map of Kejimikujik Lake, NTS sheet 21A/06. Nova Scotia Department of Mines and Energy, Open File Map 89-013, scale 1:50,000.

\_\_\_\_\_. 1994. Geological map of Kejimikujik Lake, NTS sheet 21A/06 and Part of 21A/07. Nova Scotia Department of Natural Resources, Map 94-5, scale 1:50,000.

HORNE, R.J., COREY, M.C., HAM, L.J. and MacDONALD, M.A. 1988. Primary and secondary structural features in the eastern portion of the South Mountain Batholith, southwestern Nova Scotia: Implications for regional stress orientations during intrusion. *Maritime Sediments and Atlantic Geology*, 24, 1, pp. 71-82.

\_\_\_\_\_. 1989. Lithogeochemical variation within the biotite-rich envelope rocks of the eastern South Mountain Batholith: Implications for its intrusive and post-intrusive history. Nova Scotia Department of Mines and Energy. Report 89-1, pp. 37-50.

\_\_\_\_\_. 1991. Variation in the mafic mineral content of the Scrag Lake Pluton, South Mountain Batholith: Evidence for a zoned pluton. Nova Scotia Department of Natural Resources, Report 91-1, pp. 1-12.

\_\_\_\_\_. 1992. Structure and emplacement of the South Mountain Batholith, southwestern Nova Scotia. *Atlantic Geology*, 29, pp. 29-50.

- HOWIE, R.D. and BARSS, M.S. 1975. Upper Paleozoic rocks of the Atlantic Provinces, Gulf of St. Lawrence, and adjacent continental shelf. *In* Offshore Geology of Eastern Canada. Geological Survey of Canada, Paper 74-30, Volume 2, 258 p.
- HYNDMAN, D.W. 1972. Petrology of igneous and metamorphic rocks. McGraw-Hill Book Company, 533 p.
- HUTTON, D.W. 1988. Granite emplacement mechanisms and tectonic control: inferences from deformational studies. Transactions of the Royal Society of Edinburgh. Earth Sciences, 79 pp. 245-255.
- ISHIHARA, S. 1977. The magnetite-series and ilmenite-series granitic rocks. Mining Geology, 27, pp. 293-305.
- JAMIESON, R.A. 1974. The contact of the South Mountain Batholith near Mount Uniacke, Nova Scotia; unpublished B.Sc. thesis, Dalhousie University, 52 p.
- JENSEN, L. R. 1987: Report on geological and till geochemical surveys, and drilling, with drill core assays; base metals, precious metals, Kempt Snare Lake, Yarmouth County, Nova Scotia, Kidd Creek Mines Limited; Nova Scotia Department of Mines and Energy, Assessment Report AR 87-121.
- KEMPSTER, R.M.F., CLARKE, D.B., REYNOLDS, P.H. and CHATTERJEE, A.K. 1989. Late Devonian lamprophyric dykes in the Meguma Zone of Nova Scotia. Canadian Journal of Earth Sciences, 26, pp. 611-613.
- KENT, G.R. 1962. On four pegmatites in southwestern Nova Scotia. Unpublished M.Sc. thesis, Dalhousie University, Halifax.
- KEPPIE, J.D. 1979 (Compiler). Geological map of the province of Nova Scotia. Nova Scotia Department of Mines and Energy map, scale 1:500,000.
- KEPPIE, J.D. and DALLMEYER, R.D. 1987. Dating transcurrent terrane accretion: an example from the Meguma and Avalon composite terranes in the northern Appalachians. Tectonics, 6, pp. 831-847.
- KEPPIE, J.D., DALLMEYER, R.D., KROGH, T.E. and AFALION, M. 1993. Dating mineralization using several isotopic methods: an example from the South Mountain Batholith, Nova Scotia, Canada. Chemical Geology (Isotope Geoscience Section), 103, pp. 251-270.
- KONTAK, D. J. 1988: The East Kemptville project: whole-rock and mineral chemistry, stable isotopes and fluid inclusion studies - progress report; *in* Mines and Minerals Branch, Report of Activities 1988, Part A, eds. D. R. MacDonald and Y. Brown; Nova Scotia Department of Mines and Energy, Report 88-3, p. 83-96.
- \_\_\_\_\_ 1990a. The East Kemptville muscovite-topaz leucogranite. I. Geological setting and whole rock geochemistry. Canadian Mineralogist, 28, pp. 787-825.
- \_\_\_\_\_ 1990b. A sulphur isotopic study of main-stage tin and base-metal mineralization at the East Kemptville tin deposit, Yarmouth County, Nova Scotia, Canada: evidence for magmatic origin of metals and sulphur. Economic Geology, 85, pp. 399-407.
- \_\_\_\_\_ 1993.  $^{34}\text{S}$  enrichment in late-stage veins, East Kemptville tin and base metal deposit, Nova Scotia, Canada: evidence for late incursion of metasedimentary-processed sulphur in a magmatic system. Economic Geology, 88, pp. 203-207.
- \_\_\_\_\_ 1994. Geological and geochemical studies of alteration processes in a fluorine-rich environment: The East Kemptville Sn-(Zn-Cu-Ag) deposit, Yarmouth County, Nova Scotia, Canada; *in* Alteration and alteration



processes associated with ore-forming systems, ed. D. R. Lentz: Geological Association of Canada, Short Course Notes, v. 11, p. 261-314.

KONTAK, D.J. and CHATTERJEE, A.K. 1992. The East Kemptville tin deposit, Yarmouth County, Nova Scotia III. A Pb isotope study of the leucogranite and mineralized greisen: Evidence for a 366 Ma metallogenic event. *Canadian Journal of Earth Sciences*, 29, pp. 1180-1196.

KONTAK, D.J., CHATTERJEE, A.K., REYNOLDS, P.H. and TAYLOR, K. 1990. A  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronological study of metamorphic and igneous rocks of the Liscomb Complex, southern Nova Scotia. Nova Scotia Department of Mines and Energy, Report 90-1, pp.33-40.

KONTAK, D.J. AND COREY, M.C. 1988. Metasomatic origin for spessartine-rich garnet in the South Mountain Batholith, Nova Scotia. *Canadian Mineralogist*, 26, pp. 315-334.

KONTAK, D.J. and CORMIER R.F. 1991. A Rb/Sr geochronological study of the East Kemptville leucogranite, East Kemptville tin deposit, Yarmouth County, Nova Scotia: evidence for multiple tectonothermal overprinting events. *Canadian Journal of Earth Sciences*, 28, pp. 209-224.

KONTAK, D.J., CORMIER, R.F., REYNOLDS, P.H. and TAYLOR, K. 1989. Preliminary results of Rb/Sr and  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronological investigations, East Kemptville Leucogranite, southwestern Nova Scotia: Evidence for a ca. 370 age of emplacement and multiple tectono-thermal overprinting events. Nova Scotia Department of Mines and Energy, Report 89-3, pp. 41-48.

KONTAK, D.J. and KYZER, K. 2001. Preliminary fluid inclusion and oxygen isotope studies of the Flintstone Rock (NTS 21A/04) silica-clay deposit, Yarmouth County, Nova Scotia. *in* Minerals and Energy Branch, Report of Activities, ed. D.R. MacDonald; Nova Scotia Department of Natural Resources 2000, Report ME 2001-1, p. 37-48.

KONTAK, D.J., MULJA, T. and HINGSTON, R. 1986. The East Kemptville Sn deposit: preliminary results from recent mapping. Nova Scotia Department of Mines and Energy, Information Series No. 12, pp. 97-103.

KONTAK, D.J., KERRICH, R. and STRONG, D.F. 1991. The role of fluids in the late-stage evolution of the South Mountain Batholith, Nova Scotia: further geochemical and oxygen isotopic studies. *Atlantic Geology*, 27, pp. 29-47.

KONTAK, D.J., MARTIN, R.F., STRONG, D.F. and RICHARD, L.R. 1991. A crystal-chemical study of alkali feldspar in the South Mountain Batholith, Nova Scotia: The significance of  $\text{P}_2\text{O}_5$  enrichment and anomalous cell structures. (abstract). Geological and Mineralogical Association of Canada Annual Meeting, Program with Abstracts, 16, p. A67.

KONTAK, D.J., O'REILLY, G.A. and CHATTERJEE, A.K. 1990. The southwest Nova Scotia Tin Domain, Yarmouth County, Nova Scotia: Implications for tin mineralization in the Meguma Terrane, Nova Scotia. *in* Mines and Minerals Branch, Report of Activities, 1989, Part B, ed. D.R. MacDonald. Nova Scotia Department of Mines and Energy, Report 90-1, pp. 13-31.

KONTAK, D.J. and STRONG, D.F. 1988. Geochemical studies of alkali feldspar in lithophile element-rich granitic suites from Newfoundland, Nova Scotia and Peru. (abstract). Geological and Mineralogical Association of Canada Annual Meeting, Program with Abstracts, 13, p. A68.

KONTAK, D.J., STRONG, D.F. and KERRICH, R. 1988. Crystal-melt+fluid phase equilibria versus late-stage fluid-rock interaction in granitic rocks of the South Mountain Batholith, Nova Scotia: Whole rock geochemistry and oxygen isotope evidence. *Maritime Sediments and Atlantic Geology*, 24, pp.97-110.

KOUKOUVELAS, I., PE-PIPER, G. and PIPER, D.J.W. (in press). Pluton emplacement by wall-rock thrusting and roof lifting: Devonian-Carboniferous plutons of the Cobequid fault zone, Nova Scotia, Canada. *Journal of Structural Geology*.

KUBILIUS, W.P. 1983. Sulphur isotopic evidence for country rock contamination of granitoids in southwestern Nova Scotia. Unpublished M.Sc. thesis, University Park, Pennsylvania State University, 103 p.

LEHMANN, B. 1990. *Metallogeny of Tin*. Springer - Verlag, Berlin, Heidelberg, 211 p.

LEECH, G.B., LOWDEN, J.A., STOCKWELL, C.H. and WANLESS, R.K. 1963. Age determinations and geological studies (including isotopic ages - Report 4). Geological Survey of Canada, Paper 63-17.

LOMBARD, P.A. (Compiler) 1991. *Geochemical Atlas of Nova Scotia: Part I, Drainage surveys*. Nova Scotia Department of Mines and Energy, Open File Map 90-015.

LOGOTHETIS, J. 1985. Economic geology of the New Ross-Vaughan Complex. In A.K. Chatterjee and D.B. Clarke (eds.), *Guide to the granites and mineral deposits of southwestern Nova Scotia*. Nova Scotia Department of Mines and Energy, Paper 85-3, pp. 41-62.

LONGSTAFFE, F.J., SMITH, T.E. and MUEHLENBACHS, K. 1980. Oxygen isotope evidence for the genesis of Upper Paleozoic granitoids from southwestern Nova Scotia. *Canadian Journal of Earth Sciences*, 17, pp. 132-141.

LOWDEN, J.A. 1960. Age determinations of the Geological Survey of Canada, Report 1. Geological Survey of Canada, Paper 60-17.

\_\_\_\_\_. 1961. Age determinations of the Geological Survey of Canada, Report 2. Geological Survey of Canada, Paper 61-17.

LOWDEN, J.A., STOCKWELL, C.H., TIPPER, H.W. and WANLESS, R.K. 1963. Age determinations and geological studies (including isotopic ages - Report 3). Geological Survey of Canada, Paper 62-17.

LOWE, Y.S. and FARSTAD, J. 1978a. Report on the 1977 reconnaissance and detailed surveys Gaspereau Lake area, Kings County, Nova Scotia. Nova Scotia Department of Mines and Energy, Assessment Report 21A/15D 54-K-25(01).

LOWE, Y.S. and FARSTAD, J. 1978b. Report on the 1977 reconnaissance and detailed surveys Dalhousie east area, Nova Scotia. Nova Scotia Department of Mines and Energy, Assessment Report 21A/10C 54-A20(01).

MacDONALD, M.A. 1981. The Mineralogy, petrography and geochemistry of the Musquodoboit Batholith. Unpubl. M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 272 p.

\_\_\_\_\_. 1985. A traverse through the southeastern part of the South Mountain Batholith: The granite geology of highway 103 between Halifax and Chester. In *Guide to the granites and mineral deposits of southwestern Nova Scotia*. Edited by A.K. Chatterjee and D.B. Clarke. Nova Scotia Department of Mines and Energy, Paper 85-3, pp. 15-26.

\_\_\_\_\_. 1993. Petrographic and geochemical variations in aplite dykes from an outcrop in the Halifax Pluton, Nova Scotia. *Atlantic Geoscience Society Annual Colloquium and Symposia*. Halifax, Nova Scotia, Program with Abstracts, p 16.

\_\_\_\_\_. 2001. Exploration for kaolin-quartz in Yarmouth County. Nova Scotia Department of Natural Resources, *Nature's Resources*, Volume 4, Number 1, ISSN 1480-1167, pp. 6-7.

MacDONALD, M.A., BONER, F.J. and LOMBARD, P.A. 1992b. Multi-media detailed geochemistry of the Brazil Lake pegmatites, Yarmouth County, Nova Scotia. Nova Scotia Department of Natural Resources, Open File Report 92-016, 40 p.

MacDONALD M.A. and CLARKE, D.B. 1991. Use of nonparametric ranking statistics to characterize magmatic and post-magmatic processes in the eastern South Mountain Batholith, Nova Scotia, Canada. *Chemical Geology*, 92, pp. 1-20.

MacDONALD, M.A., COREY, M.C., HAM, L.J. and HORNE, R.J. 1985. South Mountain Batholith Project - Bedrock mapping. Nova Scotia Department of Mines and Energy Information Series No. 9. pp. 59-62.

\_\_\_\_\_. 1987. The geology of the South Mountain Batholith: NTS sheets 21A/09, 21A/10, 21A/15 and 21A/16(west). Nova Scotia Department of Mines and Energy, Report 87-1, pp. 107-128.

\_\_\_\_\_. 1988a. South Mountain Batholith project: a progress report on bedrock mapping. Nova Scotia Department of Mines and Energy Report 88-3, pp. 109-116.

\_\_\_\_\_. 1988a. Leucogranite and leucomonzogranite in the South Mountain Batholith, southwestern, Nova Scotia. Atlantic Geoscience Society, Annual Colloquium, Antigonish, Nova Scotia. Program with Abstracts.

\_\_\_\_\_. 1992a. An overview of recent bedrock mapping and follow-up petrological studies of the South Mountain Batholith, southwestern Nova Scotia, Canada. *Atlantic Geology*, 28, pp. 7-28.

MacDONALD, M.A. and HAM, L.J. 1992. Geological map of Gaspereau Lake (N.T.S. sheets 21A/15 and part of 21H/02). Nova Scotia Department of Natural Resources, Map 92-1, scale 1:50,000.

\_\_\_\_\_. 1989a. Preliminary geological map of Weymouth, NTS sheet 21A/05. Nova Scotia Department of Mines and Energy, Open File Map 89-012, scale 1:50,000.

\_\_\_\_\_. 1989b. Preliminary geological map of Bridgetown, NTS sheet 21A/14. Nova Scotia Department of Mines and Energy, Open File Map 89-016, scale 1:50,000.

\_\_\_\_\_. 1994a. Geological map of Weymouth, NTS sheet 21A/05. Nova Scotia Department of Natural Resources, Map 94-4, scale 1:50,000.

\_\_\_\_\_. 1994b. Geological map of Bridgetown, NTS sheet 21A/14. Nova Scotia Department of Natural Resources, Map 94-8, scale 1:50,000.

MacDONALD, M.A. and HORNE, R.J. 1987. Bedrock geological map of Halifax and Sambro NTS sheets 11D/12 and part of 11D/05. Nova Scotia Department of Mines and Energy, Map 87-6, scale 1:50,000.

\_\_\_\_\_. 1988. Petrology of the zoned, peraluminous Halifax pluton, south-central Nova Scotia. *Maritime Sediments and Atlantic Geology*, 24, pp.33-46.

- MacDONALD, M.A. and O'REILLY, G.A. 1989. Gold enrichment associated with post-magmatic processes in the South Mountain Batholith, southwestern Nova Scotia. Nova Scotia Department of Mines and Energy Report 89-1, 13-25.
- MacGILLIVRAY, G. 1982. Report on gravity survey, Caledonia, Queens County, Nova Scotia. Nova Scotia Department of Mines and Energy, Assessment Report 21A06/A 51-N-06(03).
- \_\_\_\_\_. 1983. Report on drilling; tin, Caledonia, Queens County, Nova Scotia, Biliton Canada Limited. Nova Scotia Department of Mines and Energy Assessment Report 21A/06A 51-N-06(04).
- MAHONEY, K.L. 1996. The contact metamorphic aureole of the South Mountain Batholith, Nova Scotia. Unpublished M.Sc. thesis, Acadia University, 153 pp.
- MAHONEY, K.L. and RAESIDE, R.P. 1995. The contact aureole of the South Mountain Batholith, southern Nova Scotia. Program and Summaries, Nineteenth Annual Review of Activities, Nova Scotia Department of Natural Resources Report 95-2, p 60.
- MALCOLM, W. 1976. Gold fields of Nova Scotia. Geological Survey of Canada Memoir 385.
- MANIAR, P.D. and PICCOLI, P.M. 1989. Tectonic discrimination of granitoids. Geological Society of America Bulletin, 101, pp. 635-643.
- MANNING, D.A.C. and PICHEVANT, M. 1983. The role of fluorine and boron in the generation of granitic melts. In *Migmatites, Melting and Metamorphism*, Atherton, M.P. and Gribble, C.D. eds., Shiva, pp.94-109.
- MARTEL, T.A., MCGREGOR, C.D and UTTING, J., 1993. Stratigraphic significance of Upper Devonian and Lower Carboniferous miospores from the type area of the Horton Group, Nova Scotia. Canadian Journal of Earth Sciences, 30, pp. 1091-1098.
- MAILLET, L.A. and CLARKE, D.B 1985. Cordierite in the peraluminous granites of the Meguma Zone, Nova Scotia, Canada. Mineralogical Magazine, 49, pp. 695-702.
- McAUSLAN, D.A., Dickie, G.B., Sarkar, P.K., Sinclair, P.E. and Wilson, B.H., 1980. The history of discovery and the description of the East Kemptville tin deposit (Abstract). Canadian Institute of Mining and Metallurgy, 73, pp. 78-79.
- McDOUGALL, I and HARRISON, T.M. 1988. Geochronology and Thermochronology by the  $^{40}\text{Ar}/^{39}\text{Ar}$  Method. Oxford University Press, New York; Clarendon Press, Oxford, 212 p.
- McKENZIE, C.B. 1974. Petrology of the South Mountain Batholith, western Nova Scotia. Unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 164 p.
- McKENZIE, C.B. 1988. Report on till geochemistry, prospecting and geophysics, Tobeatic Lake property; BP Resources Canada. Nova Scotia Department of Natural Resources, Assessment Report AR88-295.
- McKENZIE, C.B. and CLARKE, D.B. 1975. Petrology of the South Mountain Batholith, Nova Scotia. Canadian Journal of Earth Sciences, 12, pp. 1209-1218.
- MIYASHIRO, A. 1973. Metamorphism and Metamorphic Belts. George Allen & Unwin, London, 492 p.

- MILLER, H.G. and MacDONALD, M.A. 1993. Progress report on the South Mountain Batholith geophysical project. Nova Scotia Department of Natural Resources, Report 93-1, pp. 99-105.
- MOYLE, J.E. 1985. East Kemptville tin project. In A.K. Chatterjee and D.B. Clarke (eds.), Guide to Granites and Mineral Deposits of southwestern Nova Scotia. Nova Scotia Department of Mines and Energy, Paper 85-3, pp. 199-200.
- MUECKE, G.K. and CLARKE, D.B. 1981. Geochemical evolution of the South Mountain Batholith, Nova Scotia: rare-earth-element evidence. *Canadian Mineralogist*, 19, pp. 133-146.
- MUECKE, G.K., ELIAS, P. and REYNOLDS, P.H. 1988. Hercynian/Alleghanian overprinting of an Acadian Terrane:  $^{40}\text{Ar}/^{39}\text{Ar}$  studies in the Meguma Zone, Nova Scotia, Canada. *Chemical Geology*, 73, pp. 153-167.
- O'BRIEN, B.H. 1988. A study of the Meguma Terrane in Lunenburg County, Nova Scotia. Geological Survey of Canada, Open File 1823, 80 p.
- O'REILLY, G.A. 1985. Alkali metasomatism associated with W-Sn-Ag-Au mineralization in the granitoid rocks of the Westfield-Caledonia area, Queen's County, Nova Scotia. In A.K. Chatterjee and D.B. Clarke (eds.), Guide to the Granites and Mineral Deposits of Southwestern Nova Scotia. Nova Scotia Department of Mines and Energy, Preprint of Paper 85-3, pp. 217-231.
- \_\_\_\_\_. 1987. Deep diamond drilling of the Caledonia gravity low, Queens County, Nova Scotia Department of Mines and Energy Report 87-5, pp. 95-97.
- \_\_\_\_\_. 1988. South Mountain Batholith project: mineral deposit studies. Nova Scotia Department of Mines and Energy Report 88-3, pp. 105-107.
- \_\_\_\_\_. 1992. Petrographic and geochemical evidence for a hypogene origin of granite-hosted, vein-type Mn mineralization at the New Ross Mn deposits, Lunenburg County, Nova Scotia, Canada. *Economic Geology*, 87, 1275-1300.
- O'REILLY, G.A., COREY, M.C. and FORD, K.L. 1988. The role of airborne gamma-ray spectrometry in bedrock mapping and mineral exploration: case studies from granitic rocks within the Meguma Zone, Nova Scotia. *Maritime Sediments and Atlantic Geology*, 24, pp. 47-60.
- O'REILLY, G.A., FARLEY, E.J., and CHAREST, M.H. 1982. Metasomatic-hydrothermal mineral deposits of the New Ross-Mahone Bay area, Nova Scotia. Nova Scotia Department of Mines and Energy, Paper 82-2, 96 p.
- O'REILLY, G.A., MacDONALD, M.A., KONTAK, D.J. and COREY, M.C. 1992. Granite- and metasediment-hosted mineral deposits of southwest Nova Scotia. Geological Association of Canada, Mineralogical Association of Canada, Joint Annual meeting, Wolfville '92, Field Trip C-3, Guidebook, 91 pp.
- PATINO DOUCE, A.E., JOHNSON, A.D. and RICE, J.M. 1993. Octahedral excess mixing properties in biotite: a working model with applications to geobarometry and geothermometry. *American Mineralogist*, 78, pp. 113-131.
- PATTISON, D.R.M. 1992. Stability of andalusite and sillimanite and the Al-SiO<sub>2</sub> triple point: constraints from the Balluchulish aureole, Scotland. *Journal of Geology*, 100, pp. 423-446.
- PITRE, C.V. and RICHARDSON, J.M. 1989. Paragenesis of veins of the Duck Pond tin prospect, Meguma Group, East Kemptville, Nova Scotia. *Canadian Journal of Earth Sciences*, 26, pp. 2032-2043.



- PITCHER, W.S. and BERGER, A.R. 1972. The geology of Donegal: A study of granite emplacement and unroofing. Wiley Interscience, New York, London, Sydney and Toronto, 435 p.
- REYNOLDS, P.H., CLARKE, D.B., MUECKE, G.K. and ZENTILLI, M. 1980. K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology of granitoid rocks from the Meguma Zone, southern Nova Scotia. Geological Association of Canada - Mineralogical Association of Canada. Program with Abstracts, 5, p. 77.
- REYNOLDS, P.H., KUBLICK, E.E. and MUECKE, G.K. 1973. Potassium - argon dating of slates from the Meguma Group, Nova Scotia. Canadian Journal of Earth Sciences, 10, pp. 1059-1067.
- REYNOLDS, P.H., ZENTILLI, M. and MUECKE, G.K. 1981. K-Ar and  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology of granitoid rocks from southern Nova Scotia: its bearing on the geological evolution of the Meguma Zone of the Appalachians. Canadian Journal of Earth Sciences, 18, pp. 386-394.
- REYNOLDS, P.H., ELIAS, P., MUECKE, G. K. and GRIST, A.M. 1987. Thermal history of the southwestern Meguma Zone, Nova Scotia, from an  $^{40}\text{Ar}/^{39}\text{Ar}$  and fission track study of intrusive rocks. Canadian Journal of Earth Sciences, 24, pp. 1952-1965.
- REYNOLDS, P.H. and MUECKE, G.K. 1978. Age studies on slates: applicability of the  $^{40}\text{Ar}/^{39}\text{Ar}$  stepwise outgassing method. Earth and Planetary Science Letters, 40, pp. 111-118.
- RICHARDSON, J.M. 1984. The East Kemptville deposit, Nova Scotia: geological and geochemical relationships of greisen-hosted tin (Cu-Zn) mineralization. Canadian Institute of Mining and Metallurgy District Meeting, St. John's Newfoundland, Abstract.
- RICHARDSON, J.M. 1988. Field and textural relationships of alteration and greisen-hosted mineralization at the East Kemptville tin deposit, Davis Lake Complex, southwest Nova Scotia. In R.P. Taylor and D.F. Strong (eds.), Recent Advances in the Geology of Granite-Related Mineral Deposits. Canadian Institute of Mining and Metallurgy, 39, pp. 365-279.
- RICHARDSON, J.M., BELL, K., BLENKINSOPP, J. and WADKINSON, D.H. 1989. Rb-Sr age and geochemical distinctions between the Carboniferous tin-bearing Davis Lake complex and the Devonian South Mountain Batholith, Meguma Terrane, Nova Scotia. Canadian Journal of Earth Sciences, 26, pp. 2044-2061.
- RICHARDSON, J.M., BLENKINSOPP, J. and BELL, K. 1990. Extreme variations in strontium initial ratios in ore-related fluids. Fluorite and phosphate minerals from the greisen-style East Kemptville tin mine, Nova Scotia, Canada. Contributions to Mineralogy and Petrology, 104, pp. 516-529.
- RICHARDSON, J.M., SPOONER, E.T.C. and McAUSLAN, D.A. 1982. The East Kemptville tin deposit, Nova Scotia: An example of large tonnage, low grade, greisen-hosted tin mineralization. Geological Survey of Canada, Current Research, 82-1B, pp. 27-32.
- ROGERS, H.D. 1981. Report on geology, soil geochemical and airborne radiometric surveys, Cloud Lake, Kings County, Nova Scotia. Aquitaine Company of Canada Limited. Nova Scotia Dept. of Natural Resources Assessment Report 54-A-29(04) 434319.
- ROGERS, P.J., CHATTERJEE, A.K. and AUCOTT, J.W. 1990. Metallogenic domains and their reflection in regional lake sediment surveys from the Meguma Zone, southern Nova Scotia, Canada. Journal of Geochemical Exploration, 39, pp. 153-174.
- ROGERS, P.J. and GARRETT, R.G. 1987. Lithophile elements and exploration using centre-lake bottom sediments from the East Kemptville area, southern Nova Scotia, Canada. Journal of Geochemical Exploration, 28, pp. 467-478.

ROGERS, P.J. and LOMBARD, P.A. 1990. Regional geochemical surveys conducted by the Nova Scotia Department of Mines and Energy from 1957 to 1989. Nova Scotia Department of Mines and Energy Open File Report 90-017, 63 p.

ROGERS, P.J., MacDONALD, M.A. and RIGBY, D.W. 1985. Regional lake sediment survey of the Meguma Zone, southern Nova Scotia: new analytical data. Nova Scotia Department of Mines and Energy Open File Report 605.

RUFFMAN, A. and GREENOUGH J.D. 1990. The Weekend dykes, a newly recognized mafic dyke swarm on the eastern shore of Nova Scotia, Canada, *Canadian Journal of Earth Sciences*, 27, pp. 644-648.

SEAL, R.R. II, CLARKE, A.H. and MORRISY, C.J. 1988. Lake George, southwestern New Brunswick: a Silurian, multi-stage, polymetallic (Sb-W-Mo-Au-base metal) hydrothermal centre. In R.P. Taylor and D.F. Strong (editors). *Recent Advances in the Geology of Granite-Related Mineral Deposits*, Canadian Institute of Mining and Metallurgy, 39, pp. 365-279.

SINCLAIR, P.E., MacGILLIVRAY, G. and NEEDHAM, B. 1980. Report on geological, till and rock geochemical surveys; tin, Bezanson Lake, Lunenburg County, Nova Scotia; Shell Canada Resources Limited. Nova Scotia Department of Mines and Energy, Assessment Report 21A/09C 51-L-44(01).

SMITH, P.K. 1985. Mylonitization and fluidized brecciation in southern Nova Scotia. Nova Scotia Department of Mines and Energy Report 85-1, pp. 119-133.

SMITH, T.E. 1974. The geochemistry of the granitic rocks of Halifax County, Nova Scotia. *Canadian Journal of Earth Sciences*, 11, pp. 650-656.

\_\_\_\_\_. 1975. Layered granitic rocks at Chebucto Head, Halifax County, Nova Scotia. *Canadian Journal of Earth Sciences*, 12, pp. 456-463.

\_\_\_\_\_. 1979. The geochemistry and origin of the Devonian granitic rocks of southwest Nova Scotia. *Geological Society of America Bulletin*, Part 2, 90, pp. 850-885.

SMITH, T.E., PECK, D., HUANG, C.H. and HOLM, P.E. 1986. A re-appraisal of the alaskite/muscovite-biotite granite suite of Halifax County, Nova Scotia. *Maritime Sediments and Atlantic Geology*, 22, pp. 101-116.

SMITH, T.E. and TUREK, A. 1976. Tin-bearing potential of some Devonian granitic rocks in southwest Nova Scotia. *Mineralium Deposita*, 11, pp. 234-245.

SMITHERINGALE, W.G. 1973. Geology of parts of Digby, Bridgetown, and Gaspereau Lake map-areas. Nova Scotia. Geological Survey of Canada, Memoir 375, 78 p.

SOEHL, T.P. 1988. Geological investigation of a mineralized granitic cupola, Kempt Snare Lake, Yarmouth County, Nova Scotia. Unpublished B.Sc. thesis, Dalhousie University, Halifax, 114 p.

SOEHL, T.P., O'REILLY, G.A., CLARKE, D.B. and REYNOLDS, P.H. 1989. The graphite-bearing, Kempt Snare Lake greisenized leucogranite cupola, Yarmouth County, Nova Scotia. Nova Scotia Department of Mines and Energy Report 89-1, pp. 51-70.

STALLARD, V.A., 1975. Geochemistry of biotites as a guide to the differentiation of the South Mountain Batholith, Nova Scotia. Unpublished B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 43 p.

STRECKEISEN, A. 1976. To each plutonic rock its proper name. *Earth Sciences Review*, 12, pp. 1-33.

- STEA, R.R. 1983. Till geochemistry of southwestern Nova Scotia (sheet 5). Nova Scotia Department of Mines and Energy Open File Report 555, scale 1:100,000.
- STEA, R.R. and FOWLER, J.H. 1981. Pleistocene geology and till geochemistry of southwestern Nova Scotia, (sheet 4). Nova Scotia Department of Mines and Energy, Map 81-1, scale 1:100,000.
- STEA, R.R. and GRANT, D.R. 1982. Pleistocene geology and till geochemistry of southwestern Nova Scotia, (sheets 7 and 8) scale 1:100,000. Nova Scotia Department of Mines and Energy, Map 82-10.
- STEA, R.R. and O'REILLY, G.A. 1982. Till geochemistry of the Meguma terrane in Nova Scotia and its metallogenic implications. *In* Prospecting in Areas of Glaciated Terrain 1982. Canadian Institute of Mining and Metallurgy, p. 82-104.
- St. GEORGE, T. 1982. Assessment Report on exploration, 1981, Cloud Lake Property, Nova Scotia, 21A/15. Nova Scotia Department of Mines and Energy Assessment Report 434315.
- STRONG, D.F. 1981. Ore deposit models - 5. A model for granophile mineral deposits. *Geoscience Canada*, 8, pp. 155-161.
- STRONG, D.F. 1988. A review and model for granite-related mineral deposits. *In* Taylor, R.P. and Strong, D.F. (eds.) Recent Advances in the Geology of Granite-Related Mineral Deposits. Can. Inst. Mining and Metall. Special Volume 39, 424-425.
- TATE, M.C. 1994. The nature and origin of enclaves in four peraluminous granitoid intrusions from the Meguma Zone, Nova Scotia. *Atlantic Geology* 30, 205-215.
- TAYLOR, F.C. 1969. Geology of the Annapolis-St. Mary's Bay map-area, Nova Scotia. Geological Survey of Canada, Memoir 358, 63 p.
- TAYLOR, H.P. 1988. Oxygen, hydrogen and strontium isotope constraints on the origin of granites. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 79, pp. 317-338.
- TAYLOR, R.P., SINCLAIR, W.D. and LUTES, G. 1985. Geochemical and isotopic characterization of granites related to W-Sn-Mo mineralization in the Mount Pleasant area, New Brunswick (Extended Abstract). *In* R.P. Taylor and D.F. Strong (eds.), Granite-Related Mineral Deposits - Geology, Petrogenesis and Tectonic Setting. Canadian Institute of Mining, pp. 265-273.
- TISCHENDORF, G. 1977. Geochemical and petrographic characteristics of silicic magmatic rocks associated with rare-element mineralization. *In* Stempok, M., Burnol, L and Tischendorf, G (eds.) Metallization Associated with Acid Magmatism, Volume 2. Czechoslovakian Geological Survey, 41-92.
- UTTING, J., KEPPIE, J.D. and GILES, P.S. 1989. Palynology and age of the Lower Carboniferous Horton Group. *Contributions to Canadian Paleontology. Geological Survey of Canada Bulletin* 396, pp. 117-143.
- WALLACE, J.D., BINGLEY, J.M. and SHEA, F.S. 1963. Geological and geochemical investigation of tin bearing area of New Ross, Lunenburg County, Nova Scotia Department of Mines Open File Report 048. 50 p.
- WEEKS, E.J. 1946. Manganese, New Ross. Nova Scotia Department of Mines. Annual Report on Mines, 1945. pp. 135-166.

- WHITE, A.J.R., CLEMENS, J.D., HOLLOWAY, J.R., SILVER, L.T., CHAPPELL, B.W. and WALL, V.J. 1986. S-type granites and their probable absence in southwestern North America. *Geology*, 14, pp. 115-118.
- WHITE, A.J.R. and CHAPPELL, B.W. 1988. Some supracrustal (S-type) granites of the Lachlan Fold Belt. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 79, pp. 169-181.
- WILLIAMS, H. and HATCHER, R.D. Jr. 1983. Appalachian suspect terranes. *Geological Society of America. Memoir* 158, pp. 33-53.
- WILSON, B. 1978. Geology of the Caledonia project area Queens County, Nova Scotia, NTS 21A/06 and 21A/07. Nova Scotia Department of Mines and Energy Assessment Report 21A/06A 51-N-06(02).
- WOLFSON, I. 1983. A study of the tin mineralization and lithogeochemistry in the area of the Wedgeport pluton, southwestern Nova Scotia. unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.
- WRIGHT, W.J. 1931. Data on the method of granitic intrusion in Nova Scotia. *Transactions of the Royal Society of Canada*, 25, 3<sup>rd</sup> Series, Sec. 4, pp.309-330.
- ZEN, E. 1986. Aluminum enrichment in silicate melts by fractional crystallization: some mineralogic and petrographic considerations. *Journal of Petrology*, 27, pp. 1095-1117.
- ZENTILLI, M. and REYNOLDS, P.H. 1985.  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of micas from the East Kemptville tin deposit, Yarmouth County, Nova Scotia. *Canadian Journal of Earth Sciences*, 22, pp.1546-1548.

## APPENDIX A



# CLOUD LAKE PLUTON (CLP)

| SAMPLE                | A15-0080 | A15-0080-2 | A15-0081 | A15-0087 | A15-116 | A15-116-2 | A15-116-3 | A15-118 |
|-----------------------|----------|------------|----------|----------|---------|-----------|-----------|---------|
| Rock Type             | BGD      | BGD        | BGD      | BGD      | BMG     | BMG       | BMG       | BMG     |
| Major Elements (wt %) |          |            |          |          |         |           |           |         |
| SiO2                  | 64.72    | 70.58      | 65.36    | 60.85    | 68.30   | 68.77     | 69.05     | 67.82   |
| Al2O3                 | 16.63    | 15.30      | 15.33    | 18.70    | 14.80   | 14.73     | 14.39     | 15.06   |
| Fe2O3                 | 4.89     | 2.25       | 5.98     | 6.36     | 4.29    | 4.05      | 4.28      | 4.35    |
| CaO                   | 3.07     | 1.33       | 2.38     | 0.96     | 1.73    | 1.63      | 1.59      | 1.44    |
| MgO                   | 2.13     | 1.37       | 1.80     | 2.04     | 1.45    | 1.43      | 1.40      | 1.80    |
| Na2O                  | 3.98     | 3.99       | 3.33     | 2.13     | 3.24    | 3.45      | 3.36      | 3.73    |
| K2O                   | 2.64     | 3.95       | 3.46     | 4.48     | 3.97    | 4.24      | 4.23      | 3.85    |
| TiO2                  | 0.77     | 0.31       | 0.82     | 0.88     | 0.56    | 0.53      | 0.56      | 0.59    |
| P2O5                  | 0.28     | 0.17       | 0.24     | 0.16     | 0.20    | 0.19      | 0.18      | 0.20    |
| MnO                   | 0.08     | 0.06       | 0.11     | 0.18     | 0.09    | 0.09      | 0.09      | 0.09    |
| H2O                   | 0.40     | 0.50       | 0.41     | 2.48     | 0.40    | 0.11      | 0.12      | 0.52    |
| Normative Mineralogy  |          |            |          |          |         |           |           |         |
| Q                     | 22.68    | 28.02      | 25.94    | 27.55    | 29.34   | 27.62     | 28.56     | 26.45   |
| OR                    | 15.74    | 23.53      | 20.71    | 27.39    | 23.81   | 25.30     | 25.24     | 23.02   |
| AB                    | 33.95    | 33.99      | 28.51    | 18.63    | 27.79   | 29.45     | 28.68     | 31.90   |
| AN                    | 13.51    | 5.52       | 10.36    | 3.84     | 7.37    | 6.90      | 6.77      | 5.90    |
| C                     | 2.33     | 2.46       | 2.38     | 9.28     | 2.54    | 1.97      | 1.84      | 2.64    |
| EN                    | 5.35     | 3.44       | 4.54     | 5.25     | 3.66    | 3.59      | 3.52      | 4.53    |
| IL                    | 0.17     | 0.13       | 0.24     | 0.40     | 0.20    | 0.19      | 0.19      | 0.19    |
| HM                    | 4.93     | 2.27       | 6.05     | 6.57     | 4.35    | 4.09      | 4.32      | 4.40    |
| RU                    | 0.69     | 0.24       | 0.70     | 0.70     | 0.46    | 0.43      | 0.46      | 0.49    |
| AP                    | 0.65     | 0.40       | 0.56     | 0.38     | 0.47    | 0.44      | 0.42      | 0.47    |
| A/CNK                 | 1.11     | 1.15       | 1.13     | 1.85     | 1.16    | 1.11      | 1.11      | 1.17    |
| TTDI                  | 72.37    | 85.54      | 75.17    | 73.57    | 80.95   | 82.37     | 82.48     | 81.37   |
| Col. Ind.             | 10.45    | 5.83       | 10.83    | 12.22    | 8.21    | 7.87      | 8.03      | 9.12    |
| Trace Elements (ppm*) |          |            |          |          |         |           |           |         |
| Ba                    | 562      | 551        | 819      | 1101     | 581     | 599       | 625       | 546     |
| Rb                    | 141      | 141        | 130      | 164      | 151     | 172       | 164       | 158     |
| Sr                    | 209      | 150        | 179      | 166      | 133     | 124       | 119       | 127     |
| Zr                    | 162      | 97         | 286      | 220      | 214     | 200       | 211       | 208     |
| Nb                    | 12       | 8          | 15       | 15       | 13      | 12        | 12        | 13      |
| V                     | 61       | 27         | 65       | 106      | 36      | 41        | 40        | 47      |
| Y                     | 27       | 16         | 48       | 43       | 45      | 43        | 46        | 45      |
| Ga                    | 22       | 17         | 21       | 25       | 18      | 19        | 20        | 17      |
| Cu                    | 28       | 0          | 13       | 35       | 8       | 9         | 10        | 11      |
| Zn                    | 83       | 45         | 84       | 98       | 60      | 59        | 68        | 59      |
| Hf                    | 5        | 3          | 10       | 7        | 7       | 7         | 6         | 7       |
| Ta                    | 1.0      | 0.6        | 1.4      | 1.3      | 1.2     | 1.3       | 1.0       | 1.4     |
| Sc                    | 13.0     | 5.7        | 16.0     | 15.0     | 11.0    | 10.0      | 10.0      | 12.0    |
| La                    | 25       | 21         | 48       | 51       | 34      | 35        | 34        | 35      |
| Th                    | 8.4      | 10.0       | 15.0     | 15.0     | 12.0    | 13.0      | 12.0      | 13.0    |
| U                     | 4.2      | 2.7        | 3.4      | 4.2      | 3.7     | 4.7       | 2.8       | 3.1     |
| Li                    | 65       | 49         | 51       | 69       | 57      | 66        | 62        | 62      |
| F                     | 635      | 330        | 710      | 450      | 725     | 730       | 705       | 650     |
| As                    | 1.7      | 0.0        | 3.8      | 18.0     | 2.1     | 2.2       | 3.3       | 5.2     |
| Sn                    | 0        | 3          | 2        | 0        | 0       | 3         | 9         | 5       |
| W                     | 0        | 0          | 0        | 0        | 2       | 3         | 0         | 0       |

## CLP cont.

| SAMPLE                         | A15-120-2 | A15-141-2 | A14-001 | A14-002 | A14-002-1 | A14-003 | A14-008 | A14-1030 |
|--------------------------------|-----------|-----------|---------|---------|-----------|---------|---------|----------|
| Rock Type                      | BMG       | BMG       | BMG     | BMG     | BMG       | BMG     | BMG     | BMG      |
| SiO <sub>2</sub>               | 67.23     | 67.46     | 69.74   | 68.97   | 69.28     | 69.44   | 69.58   | 70.22    |
| Al <sub>2</sub> O <sub>3</sub> | 15.13     | 15.02     | 14.79   | 15.31   | 14.95     | 14.71   | 14.83   | 14.66    |
| Fe <sub>2</sub> O <sub>3</sub> | 4.71      | 4.30      | 3.70    | 4.00    | 4.02      | 4.47    | 4.07    | 3.55     |
| CaO                            | 1.94      | 1.63      | 1.35    | 1.66    | 1.59      | 1.72    | 1.46    | 1.50     |
| MgO                            | 1.46      | 1.59      | 1.39    | 1.51    | 1.33      | 1.68    | 1.36    | 1.21     |
| Na <sub>2</sub> O              | 3.70      | 3.88      | 3.38    | 2.57    | 3.24      | 2.65    | 3.52    | 3.48     |
| K <sub>2</sub> O               | 3.88      | 4.09      | 4.15    | 4.02    | 4.20      | 3.98    | 4.05    | 4.27     |
| TiO <sub>2</sub>               | 0.62      | 0.55      | 0.45    | 0.51    | 0.51      | 0.58    | 0.50    | 0.43     |
| P <sub>2</sub> O <sub>5</sub>  | 0.19      | 0.18      | 0.18    | 0.20    | 0.20      | 0.19    | 0.18    | 0.18     |
| MnO                            | 0.09      | 0.10      | 0.09    | 0.09    | 0.09      | 0.09    | 0.10    | 0.08     |
| H <sub>2</sub> O               | 0.20      | 0.38      | 0.70    | 0.60    | 0.40      | 0.10    | 0.40    | 0.20     |
| Q                              | 25.31     | 24.16     | 29.96   | 33.77   | 29.69     | 33.29   | 29.04   | 29.23    |
| OR                             | 23.19     | 24.49     | 24.74   | 24.06   | 24.99     | 23.66   | 24.04   | 25.36    |
| AB                             | 31.64     | 33.23     | 28.82   | 22.00   | 27.58     | 22.53   | 29.89   | 29.57    |
| AN                             | 8.47      | 6.99      | 5.56    | 7.01    | 6.62      | 7.33    | 6.09    | 6.29     |
| C                              | 1.79      | 1.70      | 2.73    | 4.24    | 2.67      | 3.38    | 2.44    | 2.02     |
| EN                             | 3.67      | 4.01      | 3.49    | 3.80    | 3.33      | 4.20    | 3.40    | 3.03     |
| IL                             | 0.19      | 0.22      | 0.19    | 0.19    | 0.19      | 0.19    | 0.21    | 0.17     |
| HM                             | 4.76      | 4.35      | 3.73    | 4.05    | 4.04      | 4.49    | 4.08    | 3.56     |
| RU                             | 0.52      | 0.44      | 0.35    | 0.41    | 0.41      | 0.48    | 0.39    | 0.34     |
| AP                             | 0.45      | 0.42      | 0.42    | 0.47    | 0.47      | 0.44    | 0.42    | 0.42     |
| A/CNK                          | 1.10      | 1.09      | 1.18    | 1.32    | 1.17      | 1.25    | 1.16    | 1.12     |
| TTDI                           | 80.14     | 81.87     | 83.52   | 79.83   | 82.26     | 79.48   | 82.97   | 84.16    |
| Col. Ind.                      | 8.63      | 8.58      | 7.41    | 8.05    | 7.57      | 8.89    | 7.70    | 6.76     |
| Ba                             | 642       | 643       | 487     | 565     | 606       | 604     | 595     | 519      |
| Rb                             | 151       | 174       | 187     | 172     | 169       | 173     | 175     | 182      |
| Sr                             | 143       | 126       | 119     | 123     | 127       | 134     | 127     | 112      |
| Zr                             | 219       | 207       | 173     | 196     | 202       | 211     | 194     | 186      |
| Nb                             | 12        | 13        | 12      | 11      | 13        | 15      | 14      | 11       |
| V                              | 51        | 39        | 30      | 33      | 33        | 39      | 30      | 29       |
| Y                              | 48        | 43        | 42      | 38      | 42        | 39      | 37      | 41       |
| Ga                             | 21        | 21        | 16      | 16      | 17        | 18      | 16      | 19       |
| Cu                             | 9         | 6         | 0       | 0       | 0         | 0       | 0       | 0        |
| Zn                             | 70        | 67        | 56      | 61      | 66        | 61      | 54      | 56       |
| Hf                             | 8         | 7         | 7       | 8       | 9         | 8       | 7       | 6        |
| Ta                             | 1.3       | 1.3       | 1.5     | 1.2     | 1.2       | 1.1     | 1.2     | 1.0      |
| Sc                             | 12.0      | 11.0      | 7.5     | 9.1     | 10.0      | 9.3     | 9.0     | 7.2      |
| La                             | 38        | 35        | 31      | 35      | 38        | 34      | 34      | 31       |
| Th                             | 13.0      | 13.0      | 13.0    | 13.0    | 14.0      | 12.0    | 12.0    | 12.0     |
| U                              | 4.5       | 3.4       | 3.8     | 3.5     | 3.2       | 3.3     | 3.7     | 3.5      |
| Li                             | 59        | 63        | 59      | 59      | 53        | 62      | 58      | 62       |
| F                              | 730       | 735       | 695     | 633     | 570       | 698     | 566     | 628      |
| As                             | 13.0      | 5.0       | 9.0     | 2.1     | 2.1       | 30.0    | 2.0     | 1.5      |
| Sn                             | 1         | 0         | 13      | 7       | 2         | 11      | 10      | 5        |
| W                              | 0         | 0         | 0       | 3       | 1         | 1       | 3       | 1        |

## CLP cont.

| SAMPLE                         | A15-0142 | A14-1040 | A14-C002A | A14-C004 | A14-1006 | A14-1006-1 | A14-1007 | A15-0087-G |
|--------------------------------|----------|----------|-----------|----------|----------|------------|----------|------------|
| Rock Type                      | FGLMG    | FGLMG    | FGLMG     | FGLMG    | FGLMG    | FGLMG      | FGLMG    | APLI       |
| SiO <sub>2</sub>               | 75.27    | 76.25    | 75.64     | 76.10    | 75.38    | 75.23      | 75.16    | 68.73      |
| Al <sub>2</sub> O <sub>3</sub> | 13.36    | 13.47    | 13.62     | 13.74    | 13.72    | 13.53      | 13.76    | 17.01      |
| Fe <sub>2</sub> O <sub>3</sub> | 1.47     | 1.20     | 1.30      | 0.98     | 1.15     | 1.30       | 1.18     | 0.76       |
| CaO                            | 0.28     | 0.23     | 0.24      | 0.37     | 0.28     | 0.22       | 0.25     | 0.89       |
| MgO                            | 0.75     | 0.82     | 0.77      | 0.87     | 0.73     | 0.87       | 0.79     | 0.72       |
| Na <sub>2</sub> O              | 3.67     | 3.13     | 3.80      | 3.59     | 4.31     | 4.09       | 3.82     | 4.42       |
| K <sub>2</sub> O               | 4.71     | 4.62     | 4.22      | 3.54     | 4.19     | 4.54       | 4.48     | 6.02       |
| TiO <sub>2</sub>               | 0.06     | 0.06     | 0.03      | 0.04     | 0.03     | 0.04       | 0.04     | 0.03       |
| P <sub>2</sub> O <sub>5</sub>  | 0.13     | 0.16     | 0.14      | 0.14     | 0.16     | 0.15       | 0.12     | 0.21       |
| MnO                            | 0.07     | 0.07     | 0.06      | 0.02     | 0.05     | 0.07       | 0.08     | 0.14       |
| H <sub>2</sub> O               | 0.13     | 0.40     | 0.40      | 0.40     | 0.40     | 0.40       | 0.80     | 0.34       |
| Q                              | 34.61    | 39.08    | 36.17     | 40.21    | 33.02    | 32.69      | 34.51    | 17.76      |
| OR                             | 27.92    | 27.32    | 25.01     | 21.07    | 24.78    | 26.84      | 26.58    | 35.99      |
| AB                             | 31.12    | 26.48    | 32.21     | 30.56    | 36.47    | 34.59      | 32.42    | 37.80      |
| AN                             | 0.54     | 0.09     | 0.27      | 0.92     | 0.34     | 0.11       | 0.46     | 3.07       |
| C                              | 2.03     | 3.28     | 2.70      | 3.69     | 1.97     | 1.84       | 2.46     | 2.13       |
| EN                             | 1.87     | 2.04     | 1.92      | 2.18     | 1.82     | 2.17       | 1.97     | 1.81       |
| IL                             | 0.11     | 0.11     | 0.06      | 0.04     | 0.06     | 0.08       | 0.08     | 0.06       |
| HM                             | 1.44     | 1.16     | 1.23      | 0.99     | 1.10     | 1.22       | 1.08     | 0.51       |
| RU                             | 0.00     | 0.00     | 0.00      | 0.02     | 0.00     | 0.00       | 0.00     | 0.00       |
| AP                             | 0.30     | 0.37     | 0.33      | 0.33     | 0.37     | 0.35       | 0.28     | 0.49       |
| A/CNK                          | 1.15     | 1.27     | 1.21      | 1.32     | 1.13     | 1.12       | 1.19     | 1.10       |
| TTDI                           | 93.65    | 92.88    | 93.38     | 91.84    | 94.27    | 94.12      | 93.52    | 91.55      |
| Col. Ind.                      | 3.48     | 3.37     | 3.31      | 3.21     | 3.05     | 3.58       | 3.28     | 2.75       |
| Ba                             | 91       | 72       | 36        | 67       | 123      | 23         | 22       | 394        |
| Rb                             | 259      | 276      | 288       | 213      | 286      | 307        | 283      | 240        |
| Sr                             | 16       | 10       | 13        | 39       | 20       | 12         | 11       | 97         |
| Zr                             | 58       | 40       | 39        | 46       | 45       | 44         | 43       | 43         |
| Nb                             | 7        | 7        | 5         | 7        | 6        | 7          | 8        | 0          |
| V                              | 0        | 0        | 0         | 16       | 0        | 0          | 0        | 0          |
| Y                              | 32       | 20       | 24        | 20       | 20       | 26         | 23       | 22         |
| Ga                             | 16       | 16       | 16        | 19       | 18       | 16         | 18       | 16         |
| Cu                             | 0        | 0        | 0         | 52       | 0        | 0          | 0        | 89         |
| Zn                             | 28       | 25       | 51        | 25       | 36       | 43         | 21       | 11         |
| Hf                             | 2        | 2        | 2         | 1        | 2        | 2          | 2        | 2          |
| Ta                             | 1.7      | 1.3      | 1.7       | 1.7      | 2.2      | 1.8        | 1.8      | 0.0        |
| Sc                             | 3.1      | 3.1      | 2.4       | 3.5      | 2.9      | 3.1        | 3.2      | 2.9        |
| La                             | 6        | 4        | 4         | 5        | 3        | 4          | 4        | 24         |
| Th                             | 5.3      | 3.0      | 3.9       | 4.2      | 4.3      | 4.3        | 4.2      | 15.0       |
| U                              | 3.5      | 1.6      | 7.8       | 13.0     | 4.5      | 4.8        | 4.8      | 10.0       |
| Li                             | 65       | 106      | 21        | 19       | 21       | 57         | 41       | 12         |
| F                              | 270      | 327      | 63        | 177      | 160      | 317        | 120      | 70         |
| As                             | 12.0     | 8.6      | 8.4       | 22.0     | 17.0     | 7.3        | 17.0     | 1.6        |
| Sn                             | 9        | 11       | 0         | 0        | 0        | 0          | 0        | 2          |
| W                              | 3        | 5        | 3         | 8        | 11       | 4          | 1        | 0          |

# FIVE ISLAND LAKE PLUTON (FIP)

| SAMPLE                | D13-2001 | D13-2003 | D13-2004 | D13-2030 | D13-2058 | D13-2078 | D13-2091-1 | D13-2118 |
|-----------------------|----------|----------|----------|----------|----------|----------|------------|----------|
| Rock Type             | BGD      | BGD      | BGD      | BGD      | BGD      | BGD      | BGD        | BGD      |
| Major Elements (wt %) |          |          |          |          |          |          |            |          |
| SiO2                  | 68.75    | 68.79    | 67.26    | 68.10    | 69.17    | 66.23    | 65.14      | 64.04    |
| Al2O3                 | 15.19    | 15.42    | 15.10    | 15.22    | 15.35    | 16.55    | 15.93      | 16.87    |
| Fe2O3                 | 3.81     | 3.32     | 5.06     | 3.87     | 3.41     | 4.34     | 5.34       | 5.15     |
| CaO                   | 1.43     | 1.60     | 2.37     | 2.14     | 1.05     | 2.17     | 1.67       | 2.55     |
| MgO                   | 1.81     | 1.59     | 1.74     | 1.69     | 1.49     | 1.99     | 2.48       | 2.25     |
| Na2O                  | 3.38     | 3.14     | 2.99     | 3.31     | 3.70     | 3.46     | 4.31       | 3.79     |
| K2O                   | 3.62     | 3.87     | 3.18     | 3.71     | 4.28     | 4.02     | 2.86       | 3.10     |
| TiO2                  | 0.59     | 0.51     | 0.83     | 0.59     | 0.50     | 0.66     | 0.81       | 0.77     |
| P2O5                  | 0.23     | 0.24     | 0.21     | 0.19     | 0.24     | 0.20     | 0.24       | 0.25     |
| MnO                   | 0.08     | 0.07     | 0.08     | 0.08     | 0.07     | 0.08     | 0.07       | 0.09     |
| H2O                   | 0.90     | 0.90     | 0.60     | 0.50     | 0.90     | 0.40     | 1.70       | 1.10     |
| Normative Mineralogy  |          |          |          |          |          |          |            |          |
| Q                     | 30.81    | 31.03    | 30.97    | 28.38    | 27.66    | 23.72    | 22.78      | 22.26    |
| OR                    | 21.70    | 23.23    | 19.03    | 22.19    | 25.50    | 23.85    | 17.11      | 18.55    |
| AB                    | 28.98    | 26.96    | 25.60    | 28.32    | 31.54    | 29.36    | 36.89      | 32.44    |
| AN                    | 5.66     | 6.46     | 10.51    | 9.48     | 3.67     | 9.48     | 6.79       | 11.14    |
| C                     | 3.71     | 3.78     | 2.97     | 2.35     | 3.32     | 3.05     | 3.32       | 3.28     |
| EN                    | 4.06     | 4.02     | 4.38     | 4.26     | 3.74     | 4.97     | 6.25       | 5.67     |
| IL                    | 0.17     | 0.15     | 0.17     | 0.17     | 0.15     | 0.17     | 0.15       | 0.19     |
| HM                    | 3.86     | 3.37     | 5.12     | 3.91     | 3.44     | 4.35     | 5.40       | 5.21     |
| RU                    | 0.51     | 0.44     | 0.75     | 0.51     | 0.42     | 0.57     | 0.74       | 0.68     |
| AP                    | 0.54     | 0.56     | 0.49     | 0.45     | 0.56     | 0.47     | 0.56       | 0.59     |
| A/CNK                 | 1.26     | 1.26     | 1.19     | 1.14     | 1.22     | 1.18     | 1.20       | 1.19     |
| TTDI                  | 81.48    | 81.21    | 75.61    | 78.88    | 84.71    | 76.94    | 76.78      | 73.25    |
| Col. Ind.             | 8.10     | 7.54     | 9.68     | 8.34     | 7.32     | 9.50     | 11.80      | 11.07    |
| Trace Elements (ppm*) |          |          |          |          |          |          |            |          |
| Ba                    | 537      | 479      | 670      | 708      | 489      | 790      | 681        | 756      |
| Rb                    | 150      | 158      | 121      | 130      | 191      | 148      | 91         | 127      |
| Sr                    | 137      | 126      | 191      | 192      | 124      | 204      | 178        | 236      |
| Zr                    | 157      | 135      | 226      | 164      | 140      | 201      | 220        | 238      |
| Nb                    | 12       | 10       | 13       | 11       | 10       | 12       | 14         | 14       |
| V                     | 46       | 40       | 70       | 45       | 38       | 53       | 74         | 57       |
| Y                     | 22       | 23       | 31       | 29       | 21       | 30       | 32         | 31       |
| Ga                    | 21       | 22       | 20       | 21       | 20       | 22       | 23         | 21       |
| Cu                    | 0        | 4        | 13       | 1        | 6        | 12       | 1          | 11       |
| Zn                    | 58       | 61       | 72       | 55       | 66       | 62       | 43         | 90       |
| Hf                    | 5        | 4        | 7        | 6        | 4        | 6        | 8          | 8        |
| Ta                    | 1.1      | 1.0      | 1.0      | 1.0      | 1.1      | 1.2      | 1.1        | 0.8      |
| Sc                    | 9.4      | 8.3      | 12.0     | 10.0     | 7.2      | 11.0     | 13.0       | 13.0     |
| La                    | 31       | 24       | 42       | 34       | 28       | 42       | 44         | 45       |
| Th                    | 12.0     | 11.0     | 13.0     | 12.0     | 14.0     | 14.0     | 15.0       | 15.0     |
| U                     | 3.2      | 4.2      | 2.8      | 2.1      | 3.0      | 2.8      | 2.4        | 2.6      |
| Li                    | 52       | 68       | 39       | 38       | 50       | 54       | 53         | 56       |
| F                     | 490      | 610      | 710      | 580      | 510      | 490      | 510        | 620      |
| As                    | 1.0      | 0.5      | 1.0      | 0.5      | 0.5      | 2.2      | 2.0        | 1.2      |
| Sn                    | 7        | 6        | 6        | 11       | 10       | 2        | 7          | 2        |
| W                     | 1        | 1        | 1        | 1        | 2        | 2        | 2          | 1        |

## FIP cont.

| SAMPLE<br>Rock Type            | D13-2128<br>BGD | A16-1102<br>BGD | A16-1102-D<br>BGD | A16-1103<br>BGD | A16-1103-D<br>BGD | A16-1137<br>BGD | A16-1169<br>BGD | A16-1172<br>BGD |
|--------------------------------|-----------------|-----------------|-------------------|-----------------|-------------------|-----------------|-----------------|-----------------|
| SiO <sub>2</sub>               | 66.51           | 68.94           | 65.94             | 69.65           | 69.34             | 66.35           | 67.25           | 66.89           |
| Al <sub>2</sub> O <sub>3</sub> | 16.08           | 14.93           | 15.81             | 15.26           | 15.61             | 16.35           | 14.79           | 15.86           |
| Fe <sub>2</sub> O <sub>3</sub> | 4.34            | 4.01            | 4.66              | 3.14            | 2.86              | 4.08            | 5.82            | 4.14            |
| CaO                            | 2.58            | 2.15            | 2.42              | 1.39            | 1.32              | 2.75            | 2.12            | 2.63            |
| MgO                            | 2.14            | 1.96            | 2.22              | 1.64            | 1.44              | 1.89            | 1.98            | 2.03            |
| Na <sub>2</sub> O              | 3.09            | 3.31            | 3.75              | 3.86            | 4.13              | 3.91            | 3.04            | 3.62            |
| K <sub>2</sub> O               | 3.59            | 3.16            | 3.45              | 4.22            | 4.55              | 3.31            | 3.06            | 3.42            |
| TiO <sub>2</sub>               | 0.65            | 0.61            | 0.72              | 0.42            | 0.38              | 0.61            | 0.90            | 0.63            |
| P <sub>2</sub> O <sub>5</sub>  | 0.22            | 0.19            | 0.24              | 0.15            | 0.15              | 0.19            | 0.22            | 0.19            |
| MnO                            | 0.08            | 0.07            | 0.08              | 0.07            | 0.07              | 0.08            | 0.10            | 0.08            |
| H <sub>2</sub> O               | 0.20            | 0.60            | 0.60              | 0.60            | 0.70              | 0.50            | 0.50            | 0.30            |
| Q                              | 26.88           | 30.80           | 23.26             | 26.08           | 23.37             | 22.86           | 31.20           | 24.73           |
| OR                             | 21.39           | 18.82           | 20.55             | 25.01           | 26.95             | 19.67           | 18.23           | 20.33           |
| AB                             | 26.33           | 28.19           | 31.95             | 32.72           | 35.00             | 33.24           | 25.91           | 30.78           |
| AN                             | 11.44           | 9.49            | 10.51             | 5.93            | 5.58              | 12.46           | 9.14            | 11.86           |
| C                              | 2.97            | 2.63            | 2.09              | 2.18            | 1.85              | 1.80            | 3.17            | 1.88            |
| EN                             | 5.37            | 4.91            | 5.57              | 4.09            | 3.59              | 4.73            | 4.97            | 5.08            |
| IL                             | 0.17            | 0.15            | 0.17              | 0.15            | 0.15              | 0.17            | 0.22            | 0.17            |
| HM                             | 4.37            | 4.04            | 4.69              | 3.15            | 2.86              | 4.10            | 5.86            | 4.16            |
| RU                             | 0.56            | 0.53            | 0.63              | 0.34            | 0.30              | 0.52            | 0.79            | 0.54            |
| AP                             | 0.51            | 0.44            | 0.56              | 0.35            | 0.35              | 0.44            | 0.51            | 0.44            |
| A/CNK                          | 1.18            | 1.17            | 1.11              | 1.14            | 1.11              | 1.09            | 1.22            | 1.10            |
| TTDI                           | 74.60           | 77.81           | 75.77             | 83.82           | 85.32             | 75.78           | 75.34           | 75.85           |
| Col. Ind.                      | 9.91            | 9.10            | 10.43             | 7.39            | 6.61              | 9.00            | 11.04           | 9.41            |
| Ba                             | 842             | 830             | 905               | 586             | 565               | 755             | 594             | 803             |
| Rb                             | 126             | 105             | 121               | 152             | 153               | 126             | 133             | 126             |
| Sr                             | 222             | 203             | 214               | 123             | 124               | 225             | 172             | 224             |
| Zr                             | 193             | 174             | 201               | 130             | 119               | 169             | 250             | 171             |
| Nb                             | 12              | 10              | 12                | 10              | 10                | 11              | 15              | 11              |
| V                              | 55              | 54              | 63                | 33              | 35                | 53              | 68              | 53              |
| Y                              | 33              | 21              | 25                | 31              | 29                | 28              | 36              | 26              |
| Ga                             | 19              | 19              | 22                | 19              | 21                | 22              | 23              | 24              |
| Cu                             | 9               | 4               | 6                 | 1               | 0                 | 11              | 10              | 6               |
| Zn                             | 62              | 324             | 278               | 47              | 44                | 60              | 80              | 56              |
| Hf                             | 6               | 5               | 7                 | 5               | 4                 | 5               | 8               | 6               |
| Ta                             | 1.0             | 0.8             | 0.9               | 1.1             | 0.8               | 0.9             | 1.1             | 0.9             |
| Sc                             | 10.0            | 9.0             | 12.0              | 6.8             | 7.4               | 10.0            | 14.0            | 11.0            |
| La                             | 38              | 29              | 37                | 25              | 28                | 37              | 44              | 38              |
| Th                             | 14.0            | 11.0            | 14.0              | 10.0            | 12.0              | 12.0            | 14.0            | 13.0            |
| U                              | 2.9             | 3.0             | 3.4               | 2.0             | 2.0               | 2.7             | 3.2             | 2.0             |
| Li                             | 41              | 33              | 36                | 50              | 53                | 41              | 43              | 41              |
| F                              | 570             | 620             | 650               | 530             | 570               | 600             | 680             | 670             |
| As                             | 2.0             | 1.6             | 1.4               | 0.8             | 1.2               | 1.6             | 1.8             | 1.1             |
| Sn                             | 9               | 4               | 4                 | 9               | 8                 | 8               | 8               | 9               |
| W                              | 1               | 1               | 1                 | 1               | 1                 | 1               | 1               | 1               |



## FIP cont.

| SAMPLE<br>Rock Type | A16-1172-D<br>BGD | A16-3051<br>BGD | A16-3052<br>BGD | A16-3053<br>BGD | D13-2023<br>APLI | D13-2031<br>APLI | D13-2091-2<br>APLI |
|---------------------|-------------------|-----------------|-----------------|-----------------|------------------|------------------|--------------------|
| SiO2                | 66.91             | 67.86           | 66.06           | 67.80           | 74.28            | 74.30            | 72.38              |
| Al2O3               | 15.61             | 14.57           | 15.99           | 15.35           | 14.17            | 14.43            | 14.53              |
| Fe2O3               | 4.59              | 4.26            | 4.64            | 4.29            | 3.37             | 0.54             | 1.16               |
| CaO                 | 1.77              | 2.16            | 2.41            | 2.61            | 0.09             | 0.33             | 0.42               |
| MgO                 | 1.83              | 1.78            | 2.14            | 1.92            | 1.02             | 0.66             | 0.98               |
| Na2O                | 3.84              | 3.34            | 3.32            | 3.32            | 1.41             | 3.31             | 4.53               |
| K2O                 | 3.85              | 3.52            | 3.39            | 2.99            | 3.36             | 6.14             | 4.54               |
| TiO2                | 0.67              | 0.61            | 0.73            | 0.68            | 0.18             | 0.04             | 0.17               |
| P2O5                | 0.21              | 0.21            | 0.22            | 0.19            | 0.13             | 0.12             | 0.29               |
| MnO                 | 0.10              | 0.08            | 0.09            | 0.07            | 0.02             | 0.02             | 0.03               |
| H2O                 | 0.60              | 0.80            | 0.70            | 0.60            | 2.70             | 0.60             | 0.70               |
| Q                   | 24.05             | 28.72           | 26.30           | 29.35           | 52.68            | 30.21            | 27.36              |
| OR                  | 22.91             | 21.16           | 20.26           | 17.82           | 20.26            | 36.36            | 27.12              |
| AB                  | 32.69             | 28.72           | 28.38           | 28.31           | 12.16            | 28.04            | 38.70              |
| AN                  | 7.45              | 9.49            | 10.62           | 11.80           | 0.00             | 0.85             | 0.19               |
| C                   | 2.42              | 1.87            | 3.03            | 2.38            | 8.37             | 2.02             | 2.11               |
| EN                  | 4.59              | 4.51            | 5.38            | 4.82            | 2.59             | 1.65             | 2.46               |
| IL                  | 0.22              | 0.17            | 0.19            | 0.15            | 0.04             | 0.04             | 0.06               |
| HM                  | 4.62              | 4.33            | 4.69            | 4.32            | 3.43             | 0.54             | 1.17               |
| RU                  | 0.56              | 0.53            | 0.64            | 0.61            | 0.16             | 0.02             | 0.14               |
| AP                  | 0.49              | 0.50            | 0.52            | 0.44            | 0.31             | 0.28             | 0.68               |
| A/CNK               | 1.14              | 1.10            | 1.18            | 1.14            | 2.32             | 1.14             | 1.11               |
| TTDI                | 79.65             | 78.60           | 74.93           | 75.48           | 85.10            | 94.60            | 93.18              |
| Col. Ind.           | 9.42              | 9.01            | 10.27           | 9.29            | 6.07             | 2.23             | 3.70               |
| Ba                  | 673               | 644             | 825             | 830             | 1410             | 687              | 308                |
| Rb                  | 166               | 129             | 130             | 105             | 127              | 128              | 172                |
| Sr                  | 183               | 191             | 227             | 235             | 70               | 115              | 51                 |
| Zr                  | 198               | 182             | 196             | 185             | 48               | 48               | 67                 |
| Nb                  | 13                | 11              | 14              | 11              | 4                | 4                | 9                  |
| V                   | 52                | 56              | 64              | 61              | 17               | 2                | 13                 |
| Y                   | 33                | 41              | 30              | 25              | 21               | 31               | 12                 |
| Ga                  | 23                | 22              | 22              | 24              | 16               | 12               | 21                 |
| Cu                  | 1                 | 7               | 0               | 7               | 9                | 0                | 0                  |
| Zn                  | 67                | 59              | 69              | 60              | 23               | 23               | 26                 |
| Hf                  | 7                 | 6               | 6               | 6               | 1                | 2                | 2                  |
| Ta                  | 1.1               | 0.9             | 1.0             | 0.7             | 0.5              | 0.5              | 1.2                |
| Sc                  | 11.0              | 11.0            | 11.0            | 10.0            | 7.2              | 1.0              | 2.7                |
| La                  | 38                | 41              | 39              | 37              | 12               | 10               | 8                  |
| Th                  | 12.0              | 15.0            | 12.0            | 12.0            | 4.8              | 5.0              | 6.0                |
| U                   | 2.4               | 3.1             | 2.2             | 1.3             | 3.2              | 2.8              | 4.4                |
| Li                  | 82                | 49              | 44              | 48              | 18               | 9                | 15                 |
| F                   | 750               | 610             | 660             | 590             | 340              | 120              | 230                |
| As                  | 2.1               | 1.7             | 1.7             | 1.0             | 280.0            | 1.1              | 2.6                |
| Sn                  | 10                | 8               | 9               | 8               | 6                | 7                | 16                 |
| W                   | 1                 | 1               | 1               | 1               | 1                | 1                | 2                  |

# LITTLE ROUND LAKE PLUTON (LRP)

| SAMPLE UNIT                    | A10-3108-G | A10-3109-G | A10-3121 | A10-3122 | A10-3136-1 | A10-3140 | A10-3144 | A10-3158 |
|--------------------------------|------------|------------|----------|----------|------------|----------|----------|----------|
|                                | BMG        | BMG        | BMG      | BMG      | BMG        | BMG      | BMG      | BMG      |
| Major Elements (wt %)          |            |            |          |          |            |          |          |          |
| SiO <sub>2</sub>               | 68.88      | 71.23      | 71.36    | 73.09    | 70.31      | 71.37    | 70.59    | 69.03    |
| Al <sub>2</sub> O <sub>3</sub> | 15.18      | 14.15      | 14.39    | 13.97    | 14.50      | 14.46    | 14.51    | 15.10    |
| Fe <sub>2</sub> O <sub>3</sub> | 3.59       | 3.21       | 2.82     | 2.27     | 3.43       | 2.72     | 3.10     | 3.74     |
| CaO                            | 1.56       | 1.14       | 0.59     | 0.52     | 1.36       | 0.78     | 1.15     | 1.12     |
| MgO                            | 1.36       | 1.23       | 1.11     | 1.06     | 1.32       | 1.24     | 1.27     | 1.39     |
| Na <sub>2</sub> O              | 3.26       | 2.93       | 2.84     | 2.93     | 3.43       | 3.41     | 3.48     | 2.96     |
| K <sub>2</sub> O               | 4.19       | 4.02       | 4.63     | 4.54     | 4.19       | 4.48     | 4.09     | 4.38     |
| TiO <sub>2</sub>               | 0.50       | 0.42       | 0.36     | 0.27     | 0.45       | 0.34     | 0.41     | 0.50     |
| P <sub>2</sub> O <sub>5</sub>  | 0.22       | 0.18       | 0.22     | 0.22     | 0.18       | 0.21     | 0.25     | 0.22     |
| MnO                            | 0.08       | 0.08       | 0.07     | 0.07     | 0.08       | 0.09     | 0.08     | 0.09     |
| H <sub>2</sub> O               | 0.40       | 0.59       | 0.83     | 0.97     | 0.60       | 0.74     | 0.55     | 0.55     |
| Normative Mineralogy           |            |            |          |          |            |          |          |          |
| Q                              | 29.47      | 35.52      | 35.38    | 36.97    | 30.16      | 31.73    | 31.36    | 31.65    |
| OR                             | 25.08      | 24.12      | 27.83    | 27.14    | 24.97      | 26.74    | 24.45    | 26.29    |
| AB                             | 27.91      | 25.14      | 24.42    | 25.06    | 29.24      | 29.11    | 29.76    | 25.42    |
| AN                             | 6.37       | 4.54       | 1.51     | 1.15     | 5.61       | 2.52     | 4.11     | 4.18     |
| C                              | 3.01       | 3.38       | 4.23     | 3.85     | 2.29       | 3.11     | 2.89     | 4.04     |
| EN                             | 3.43       | 3.11       | 2.81     | 2.67     | 3.31       | 3.12     | 3.20     | 3.51     |
| IL                             | 0.17       | 0.17       | 0.15     | 0.15     | 0.17       | 0.19     | 0.17     | 0.20     |
| HM                             | 3.63       | 3.26       | 2.87     | 2.29     | 3.46       | 2.74     | 3.13     | 3.80     |
| RU                             | 0.41       | 0.33       | 0.29     | 0.19     | 0.36       | 0.24     | 0.32     | 0.40     |
| AP                             | 0.52       | 0.42       | 0.52     | 0.52     | 0.42       | 0.49     | 0.59     | 0.52     |
| A/CNK                          | 1.19       | 1.26       | 1.34     | 1.31     | 1.15       | 1.22     | 1.19     | 1.30     |
| TTDI                           | 82.46      | 84.78      | 87.63    | 89.17    | 84.37      | 87.58    | 85.58    | 83.36    |
| Col. Ind.                      | 7.23       | 6.54       | 5.83     | 5.11     | 6.94       | 6.06     | 6.50     | 7.50     |
| Trace Elements (ppm*)          |            |            |          |          |            |          |          |          |
| Ba                             | 521        | 394        | 389      | 263      | 489        | 297      | 388      | 502      |
| Rb                             | 176        | 177        | 263      | 226      | 171        | 231      | 194      | 182      |
| Sr                             | 123        | 102        | 78       | 59       | 109        | 65       | 96       | 116      |
| Zr                             | 160        | 145        | 126      | 93       | 150        | 111      | 133      | 155      |
| Nb                             | 10         | 9          | 11       | 10       | 12         | 11       | 11       | 11       |
| V                              | 34         | 34         | 24       | 19       | 34         | 19       | 23       | 35       |
| Y                              | 35         | 34         | 32       | 26       | 34         | 29       | 31       | 41       |
| Ga                             | 20         | 16         | 18       | 16       | 17         | 18       | 18       | 18       |
| Cu                             | 5          | 0          | 31       | 10       | 0          | 10       | 0        | 5        |
| Zn                             | 59         | 51         | 85       | 55       | 57         | 52       | 50       | 64       |
| Hf                             | 5          | 4          | 4        | 3        | 6          | 5        | 4        | 4        |
| Ta                             | 1.2        | 1.1        | 1.6      | 1.5      | 1.2        | 1.6      | 2.0      | 1.1      |
| Sc                             | 9.0        | 7.9        | 6.3      | 4.8      | 8.3        | 6.9      | 7.6      | 10.0     |
| La                             | 28         | 25         | 24       | 14       | 26         | 22       | 22       | 26       |
| Th                             | 12.0       | 10.0       | 12.0     | 7.1      | 10.0       | 11.0     | 8.7      | 9.4      |
| U                              | 2.9        | 2.6        | 6.1      | 4.5      | 3.5        | 3.1      | 2.9      | 3.7      |
| Li                             | 73         | 66         | 84       | 67       | 66         | 92       | 78       | 85       |
| F                              | 775        | 635        | 905      | 440      | 505        | 775      | 610      | 460      |
| As                             | 4.6        | 2.2        | 10.0     | 3.0      | 2.2        | 19.0     | 2.0      | 5.7      |
| Sn                             | 9          | 7          | 15       | 10       | 9          | 4        | 6        | 12       |
| W                              | 2          | 0          | 6        | 3        | 0          | 2        | 2        | 2        |

## LRP con

| SAMPLE UNIT | A11-2300<br>BMG | A11-2301-1<br>FGLMG | A11-2301-2<br>FGLMG | A10-3129-1<br>FGLMG |
|-------------|-----------------|---------------------|---------------------|---------------------|
| SiO2        | 70.32           | 73.33               | 74.01               | 73.52               |
| Al2O3       | 13.97           | 14.52               | 14.27               | 14.54               |
| Fe2O3       | 3.68            | 1.34                | 1.46                | 1.34                |
| CaO         | 1.38            | 0.45                | 0.41                | 0.47                |
| MgO         | 1.52            | 0.90                | 0.91                | 0.78                |
| Na2O        | 2.85            | 3.77                | 3.36                | 3.78                |
| K2O         | 3.91            | 4.50                | 4.56                | 4.36                |
| TiO2        | 0.50            | 0.12                | 0.14                | 0.12                |
| P2O5        | 0.20            | 0.32                | 0.27                | 0.30                |
| MNO         | 0.08            | 0.05                | 0.05                | 0.06                |
| H2O         | 0.60            | 0.60                | 0.80                | 0.52                |
| Q           | 34.66           | 32.99               | 35.73               | 33.75               |
| OR          | 23.50           | 26.81               | 27.12               | 25.98               |
| AB          | 24.50           | 32.12               | 28.59               | 32.22               |
| AN          | 5.63            | 0.14                | 0.27                | 0.37                |
| C           | 3.07            | 3.42                | 3.73                | 3.49                |
| EN          | 3.85            | 2.26                | 2.28                | 1.96                |
| IL          | 0.17            | 0.11                | 0.11                | 0.13                |
| HM          | 3.74            | 1.35                | 1.47                | 1.35                |
| RU          | 0.42            | 0.06                | 0.08                | 0.05                |
| AP          | 0.47            | 0.75                | 0.63                | 0.70                |
| A/CNK       | 1.22            | 1.22                | 1.27                | 1.23                |
| TTDI        | 82.66           | 91.92               | 91.44               | 91.95               |
| Col. Ind.   | 7.76            | 3.71                | 3.85                | 3.44                |
| Ba          | 412             | 275                 | 147                 | 174                 |
| Rb          | 164             | 253                 | 252                 | 226                 |
| Sr          | 108             | 40                  | 33                  | 39                  |
| Zr          | 166             | 45                  | 52                  | 48                  |
| Nb          | 11              | 7                   | 8                   | 9                   |
| V           | 41              | 6                   | 0                   | 0                   |
| Y           | 31              | 19                  | 21                  | 17                  |
| Ga          | 16              | 15                  | 17                  | 16                  |
| Cu          | 0               | 0                   | 0                   | 0                   |
| Zn          | 57              | 28                  | 28                  | 23                  |
| Hf          | 5               | 0                   | 2                   | 0                   |
| Ta          | 1.5             | 2.0                 | 2.0                 | 1.5                 |
| Sc          | 8.4             | 2.3                 | 3.2                 | 2.6                 |
| La          | 27              | 7                   | 8                   | 6                   |
| Th          | 11.0            | 3.7                 | 4.8                 | 2.6                 |
| U           | 3.8             | 1.7                 | 6.6                 | 4.1                 |
| Li          | 66              | 75                  | 73                  | 120                 |
| F           | 512             | 519                 | 369                 | 320                 |
| As          | 1.8             | 3.3                 | 12.0                | 3.0                 |
| Sn          | 1               | 14                  | 12                  | 10                  |
| W           | 1               | 5                   | 4                   | 1                   |

# SCRAG LAKE PLUTON (SGP)

| SAMPLE                         | A11-2270-C | A10-3079 | A10-3085-G | A10-3086 | A10-3098-G | A10-3105 | A10-3106 | A10-3149 |
|--------------------------------|------------|----------|------------|----------|------------|----------|----------|----------|
| Rock Type                      | MP         | BGD      | BGD        | BGD      | BGD        | BGD      | BGD      | BGD      |
| Major Elements (wt %)          |            |          |            |          |            |          |          |          |
| SiO <sub>2</sub>               | 63.82      | 67.15    | 66.75      | 68.39    | 66.88      | 66.47    | 65.76    | 68.23    |
| Al <sub>2</sub> O <sub>3</sub> | 16.09      | 14.95    | 15.15      | 15.06    | 15.37      | 15.23    | 15.49    | 14.62    |
| Fe <sub>2</sub> O <sub>3</sub> | 6.36       | 4.97     | 5.10       | 4.24     | 4.94       | 5.15     | 5.36     | 3.83     |
| CaO                            | 1.74       | 2.08     | 2.01       | 1.71     | 2.04       | 2.11     | 2.35     | 1.75     |
| MgO                            | 2.12       | 1.68     | 1.78       | 1.63     | 1.77       | 1.79     | 1.84     | 1.51     |
| Na <sub>2</sub> O              | 3.14       | 3.14     | 3.42       | 3.07     | 3.24       | 3.44     | 3.34     | 3.64     |
| K <sub>2</sub> O               | 3.47       | 3.61     | 3.77       | 4.02     | 3.61       | 3.62     | 3.72     | 3.96     |
| TiO <sub>2</sub>               | 0.85       | 0.73     | 0.74       | 0.64     | 0.71       | 0.77     | 0.80     | 0.53     |
| P <sub>2</sub> O <sub>5</sub>  | 0.23       | 0.22     | 0.22       | 0.16     | 0.22       | 0.22     | 0.24     | 0.18     |
| MnO                            | 0.17       | 0.09     | 0.10       | 0.08     | 0.10       | 0.10     | 0.10     | 0.07     |
| H <sub>2</sub> O               | 1.20       | 0.47     | 0.33       | 0.69     | 0.65       | 0.23     | 0.42     | 0.57     |
| Normative Mineralogy           |            |          |            |          |            |          |          |          |
| Q                              | 26.56      | 29.12    | 26.33      | 29.79    | 28.13      | 26.31    | 25.23    | 26.85    |
| OR                             | 20.95      | 21.65    | 22.52      | 24.02    | 21.59      | 21.65    | 22.23    | 23.12    |
| AB                             | 27.11      | 26.94    | 29.22      | 26.24    | 27.72      | 29.43    | 28.54    | 31.32    |
| AN                             | 7.27       | 9.00     | 8.61       | 7.51     | 8.78       | 9.13     | 10.19    | 7.63     |
| C                              | 4.65       | 2.66     | 2.34       | 2.96     | 2.98       | 2.37     | 2.29     | 1.62     |
| EN                             | 5.39       | 4.24     | 4.49       | 4.10     | 4.46       | 4.51     | 4.63     | 3.82     |
| IL                             | 0.37       | 0.20     | 0.22       | 0.17     | 0.22       | 0.22     | 0.22     | 0.15     |
| HM                             | 6.49       | 5.04     | 5.15       | 4.28     | 5.00       | 5.21     | 5.41     | 3.90     |
| RU                             | 0.67       | 0.64     | 0.63       | 0.56     | 0.60       | 0.66     | 0.69     | 0.46     |
| AP                             | 0.54       | 0.52     | 0.52       | 0.37     | 0.52       | 0.52     | 0.56     | 0.42     |
| A/CNK                          | 1.33       | 1.16     | 1.13       | 1.20     | 1.19       | 1.14     | 1.12     | 1.09     |
| TTDI                           | 74.61      | 77.71    | 78.06      | 80.04    | 77.45      | 77.39    | 76.00    | 81.99    |
| Col. Ind.                      | 12.25      | 9.48     | 9.84       | 8.56     | 9.67       | 9.93     | 10.26    | 7.87     |
| Trace Elements                 |            |          |            |          |            |          |          |          |
| Ba                             | 744        | 625      | 634        | 702      | 630        | 623      | 795      | 505      |
| Rb                             | 135        | 145      | 149        | 134      | 144        | 143      | 149      | 158      |
| Sr                             | 181        | 156      | 152        | 153      | 162        | 160      | 171      | 129      |
| Zr                             | 294        | 229      | 213        | 197      | 211        | 228      | 239      | 170      |
| Nb                             | 14         | 12       | 13         | 11       | 12         | 13       | 13       | 11       |
| V                              | 97         | 68       | 61         | 45       | 74         | 68       | 72       | 39       |
| Y                              | 46         | 36       | 35         | 31       | 35         | 41       | 41       | 35       |
| Ga                             | 17         | 20       | 19         | 19       | 20         | 21       | 19       | 16       |
| Cu                             | 7          | 9        | 9          | 10       | 15         | 8        | 12       | 5        |
| Zn                             | 790        | 70       | 68         | 66       | 72         | 72       | 69       | 61       |
| Hf                             | 8          | 7        | 7          | 7        | 7          | 8        | 8        | 6        |
| Ta                             | 1.4        | 1.4      | 1.3        | 1.2      | 1.1        | 1.4      | 1.4      | 1.2      |
| Sc                             | 14.0       | 13.0     | 13.0       | 11.0     | 13.0       | 14.0     | 14.0     | 9.3      |
| La                             | 45         | 38       | 38         | 37       | 39         | 41       | 44       | 30       |
| Th                             | 15.0       | 14.0     | 13.0       | 15.0     | 14.0       | 14.0     | 15.0     | 11.0     |
| U                              | 3.6        | 3.2      | 3.8        | 3.4      | 2.8        | 2.5      | 2.3      | 3.3      |
| Li                             | 66         | 67       | 66         | 56       | 50         | 66       | 50       | 53       |
| F                              | 674        | 650      | 570        | 525      | 460        | 725      | 840      | 640      |
| As                             | 9.0        | 3.0      | 4.2        | 3.3      | 1.8        | 2.0      | 1.3      | 2.7      |
| Sn                             | 0          | 6        | 3          | 9        | 2          | 4        | 4        | 6        |
| W                              | 0          | 1        | 0          | 0        | 0          | 0        | 1        | 0        |

## SGP cont.

| SAMPLE<br>Rock Type            | A11-2267<br>BGD | A11-2270-B<br>BGD | A11-3002<br>BGD | A11-3019<br>BGD | A12-1015<br>BGD | A12-8007<br>BGD | A15-0007<br>BGD | A15-0014-5<br>BGD |
|--------------------------------|-----------------|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-------------------|
| SiO <sub>2</sub>               | 68.37           | 64.72             | 69.58           | 68.83           | 65.55           | 65.04           | 66.71           | 67.62             |
| Al <sub>2</sub> O <sub>3</sub> | 14.95           | 15.92             | 14.34           | 14.18           | 15.52           | 15.58           | 15.40           | 15.38             |
| Fe <sub>2</sub> O <sub>3</sub> | 4.57            | 5.70              | 3.65            | 4.46            | 5.44            | 5.84            | 4.84            | 4.39              |
| CaO                            | 2.02            | 2.07              | 1.71            | 1.83            | 2.36            | 2.41            | 1.90            | 1.37              |
| MgO                            | 1.68            | 1.96              | 1.57            | 1.69            | 1.96            | 1.95            | 1.87            | 1.72              |
| Na <sub>2</sub> O              | 2.96            | 3.33              | 3.14            | 2.88            | 3.34            | 3.55            | 3.06            | 3.10              |
| K <sub>2</sub> O               | 3.75            | 3.61              | 4.06            | 3.63            | 3.60            | 3.51            | 3.85            | 4.18              |
| TiO <sub>2</sub>               | 0.67            | 0.81              | 0.51            | 0.65            | 0.80            | 0.80            | 0.76            | 0.62              |
| P <sub>2</sub> O <sub>5</sub>  | 0.21            | 0.24              | 0.18            | 0.19            | 0.23            | 0.24            | 0.21            | 0.24              |
| MnO                            | 0.08            | 0.13              | 0.07            | 0.08            | 0.10            | 0.12            | 0.09            | 0.09              |
| H <sub>2</sub> O               | 0.40            | 0.70              | 0.60            | 0.60            | 0.55            | 0.40            | 0.70            | 0.58              |
| Q                              | 30.78           | 25.22             | 30.63           | 32.79           | 25.30           | 23.78           | 28.27           | 29.13             |
| OR                             | 22.35           | 21.68             | 24.30           | 21.82           | 21.50           | 20.96           | 23.07           | 25.05             |
| AB                             | 25.23           | 28.61             | 26.89           | 24.76           | 28.57           | 30.33           | 26.23           | 26.57             |
| AN                             | 8.71            | 8.83              | 7.39            | 7.96            | 10.32           | 10.49           | 8.16            | 5.29              |
| C                              | 2.87            | 3.39              | 2.12            | 2.68            | 2.42            | 2.15            | 3.29            | 3.89              |
| EN                             | 4.21            | 4.96              | 3.96            | 4.28            | 4.94            | 4.90            | 4.72            | 4.34              |
| IL                             | 0.17            | 0.28              | 0.15            | 0.17            | 0.23            | 0.26            | 0.20            | 0.20              |
| HM                             | 4.60            | 5.79              | 3.69            | 4.53            | 5.50            | 5.90            | 4.90            | 4.45              |
| RU                             | 0.58            | 0.67              | 0.44            | 0.57            | 0.68            | 0.67            | 0.67            | 0.53              |
| AP                             | 0.49            | 0.57              | 0.42            | 0.45            | 0.53            | 0.56            | 0.49            | 0.56              |
| A/CNK                          | 1.19            | 1.21              | 1.13            | 1.18            | 1.14            | 1.11            | 1.22            | 1.27              |
| TTDI                           | 78.35           | 75.51             | 81.82           | 79.36           | 75.38           | 75.07           | 77.57           | 80.75             |
| Col. Ind.                      | 8.99            | 11.03             | 7.80            | 8.98            | 10.67           | 11.06           | 9.82            | 8.98              |
| Ba                             | 628             | 913               | 561             | 546             | 809             | 737             | 781             | 752               |
| Rb                             | 142             | 139               | 148             | 154             | 142             | 143             | 145             | 303               |
| Sr                             | 143             | 183               | 130             | 136             | 169             | 175             | 151             | 146               |
| Zr                             | 212             | 281               | 171             | 200             | 254             | 283             | 234             | 182               |
| Nb                             | 13              | 14                | 10              | 13              | 14              | 16              | 14              | 13                |
| V                              | 59              | 74                | 51              | 63              | 76              | 60              | 62              | 53                |
| Y                              | 33              | 43                | 32              | 28              | 38              | 43              | 31              | 47                |
| Ga                             | 17              | 20                | 18              | 17              | 20              | 21              | 20              | 19                |
| Cu                             | 0               | 0                 | 0               | 0               | 5               | 0               | 2               | 13                |
| Zn                             | 70              | 96                | 61              | 77              | 82              | 84              | 87              | 103               |
| Hf                             | 6               | 8                 | 4               | 6               | 6               | 7               | 8               | 5                 |
| Ta                             | 1.1             | 1.1               | 1.0             | 1.4             | 1.0             | 1.3             | 1.9             | 1.7               |
| Sc                             | 10.0            | 13.0              | 6.2             | 9.3             | 12.0            | 14.0            | 12.0            | 9.3               |
| La                             | 36              | 42                | 29              | 32              | 39              | 42              | 43              | 30                |
| Th                             | 14.0            | 13.0              | 11.0            | 13.0            | 14.0            | 14.0            | 15.0            | 12.0              |
| U                              | 3.4             | 3.3               | 2.0             | 4.7             | 2.5             | 3.4             | 3.5             | 3.1               |
| Li                             | 46              | 60                | 81              | 46              | 45              | 60              | 116             | 220               |
| F                              | 684             | 792               | 694             | 590             | 625             | 709             | 720             | 2170              |
| As                             | 1.9             | 29.0              | 35.0            | 22.0            | 2.1             | 24.0            | 10.0            | 8.2               |
| Sn                             | 4               | 6                 | 8               | 7               | 0               | 0               | 7               | 11                |
| W                              | 0               | 0                 | 1               | 0               | 0               | 0               | 3               | 2                 |



## SGP cont.

| SAMPLE<br>Rock Type            | A15-0015<br>BGD | A15-0016<br>BGD | A15-0035<br>BGD | A15-0050<br>BGD | A15-0050-2<br>BGD | A15-007-2A<br>BGD | A15-007-2B<br>BGD | A15-0104<br>BGD |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|-------------------|-------------------|-------------------|-----------------|
| SiO <sub>2</sub>               | 67.72           | 67.30           | 66.27           | 68.09           | 66.20             | 65.36             | 68.33             | 68.60           |
| Al <sub>2</sub> O <sub>3</sub> | 15.03           | 15.55           | 15.39           | 14.07           | 15.18             | 15.44             | 14.83             | 14.13           |
| Fe <sub>2</sub> O <sub>3</sub> | 4.89            | 4.62            | 5.08            | 5.29            | 5.49              | 5.54              | 4.45              | 4.97            |
| CaO                            | 2.07            | 2.05            | 2.14            | 1.86            | 2.32              | 2.28              | 1.96              | 2.15            |
| MgO                            | 1.77            | 1.72            | 1.88            | 1.86            | 1.83              | 1.95              | 1.64              | 1.84            |
| Na <sub>2</sub> O              | 3.37            | 3.02            | 3.17            | 2.98            | 2.93              | 3.21              | 2.96              | 2.87            |
| K <sub>2</sub> O               | 3.53            | 3.92            | 3.77            | 3.82            | 3.69              | 3.76              | 3.59              | 3.13            |
| TiO <sub>2</sub>               | 0.72            | 0.67            | 0.75            | 0.79            | 0.83              | 0.84              | 0.66              | 0.80            |
| P <sub>2</sub> O <sub>5</sub>  | 0.18            | 0.20            | 0.23            | 0.23            | 0.23              | 0.25              | 0.19              | 0.22            |
| MnO                            | 0.08            | 0.08            | 0.08            | 0.13            | 0.12              | 0.10              | 0.08              | 0.09            |
| H <sub>2</sub> O               | 0.52            | 0.30            | 0.53            | 0.69            | 0.51              | 0.55              | 0.42              | 0.41            |
| Q                              | 28.21           | 28.57           | 26.99           | 30.28           | 28.31             | 25.52             | 31.67             | 33.59           |
| OR                             | 21.01           | 23.39           | 22.58           | 22.80           | 22.09             | 22.53             | 21.52             | 18.74           |
| AB                             | 28.70           | 25.78           | 27.16           | 25.44           | 25.09             | 27.51             | 25.38             | 24.58           |
| AN                             | 9.15            | 8.94            | 9.23            | 7.79            | 10.12             | 9.80              | 8.59              | 9.34            |
| C                              | 2.35            | 3.12            | 2.79            | 2.22            | 2.73              | 2.57              | 3.00              | 2.67            |
| EN                             | 4.44            | 4.32            | 4.74            | 4.67            | 4.61              | 4.92              | 4.14              | 4.64            |
| IL                             | 0.17            | 0.17            | 0.17            | 0.28            | 0.26              | 0.22              | 0.17              | 0.19            |
| HM                             | 4.92            | 4.66            | 5.14            | 5.34            | 5.56              | 5.61              | 4.51              | 5.03            |
| RU                             | 0.63            | 0.58            | 0.67            | 0.65            | 0.70              | 0.74              | 0.56              | 0.71            |
| AP                             | 0.42            | 0.47            | 0.54            | 0.54            | 0.54              | 0.59              | 0.45              | 0.52            |
| A/CNK                          | 1.14            | 1.20            | 1.17            | 1.13            | 1.16              | 1.14              | 1.20              | 1.18            |
| TTDI                           | 77.92           | 77.74           | 76.72           | 78.51           | 75.48             | 75.56             | 78.56             | 76.91           |
| Col. Ind.                      | 9.53            | 9.15            | 10.06           | 10.29           | 10.43             | 10.75             | 8.82              | 9.86            |
| Ba                             | 643             | 770             | 730             | 631             | 685               | 775               | 652               | 603             |
| Rb                             | 144             | 144             | 167             | 153             | 144               | 143               | 138               | 133             |
| Sr                             | 151             | 166             | 173             | 158             | 161               | 177               | 158               | 159             |
| Zr                             | 237             | 220             | 230             | 205             | 218               | 227               | 212               | 208             |
| Nb                             | 14              | 14              | 13              | 11              | 13                | 13                | 12                | 13              |
| V                              | 58              | 56              | 65              | 60              | 63                | 70                | 64                | 70              |
| Y                              | 43              | 28              | 42              | 46              | 35                | 36                | 35                | 35              |
| Ga                             | 16              | 25              | 18              | 17              | 21                | 18                | 16                | 18              |
| Cu                             | 11              | 6               | 17              | 8               | 11                | 10                | 10                | 10              |
| Zn                             | 69              | 79              | 79              | 70              | 73                | 76                | 67                | 69              |
| Hf                             | 7               | 8               | 7               | 6               | 7                 | 8                 | 6                 | 8               |
| Ta                             | 1.5             | 2.6             | 1.3             | 1.1             | 1.4               | 0.9               | 1.2               | 1.1             |
| Sc                             | 11.0            | 11.0            | 12.0            | 14.0            | 15.0              | 14.0              | 11.0              | 13.0            |
| La                             | 38              | 39              | 37              | 32              | 39                | 38                | 39                | 40              |
| Th                             | 16.0            | 14.0            | 13.0            | 10.0            | 13.0              | 12.0              | 13.0              | 14.0            |
| U                              | 2.8             | 2.7             | 2.3             | 2.8             | 3.2               | 2.1               | 2.0               | 3.2             |
| Li                             | 54              | 65              | 96              | 65              | 66                | 55                | 76                | 77              |
| F                              | 870             | 660             | 1105            | 645             | 725               | 470               | 780               | 825             |
| As                             | 4.1             | 4.7             | 3.4             | 8.0             | 2.0               | 2.0               | 7.8               | 3.3             |
| Sn                             | 0               | 4               | 5               | 6               | 5                 | 0                 | 2                 | 0               |
| W                              | 2               | 1               | 1               | 1               | 0                 | 0                 | 0                 | 0               |

## SGP cont.

| SAMPLE<br>Rock Type            | A06-3015<br>BMG | A06-3015-1<br>BMG | A06-3017<br>BMG | A06-3030<br>BMG | A11-2280-1<br>BMG | A11-2286<br>BMG | A11-2296<br>BMG | A11-2316<br>BMG |
|--------------------------------|-----------------|-------------------|-----------------|-----------------|-------------------|-----------------|-----------------|-----------------|
| SiO <sub>2</sub>               | 68.23           | 69.77             | 68.41           | 70.07           | 68.30             | 67.67           | 70.02           | 68.65           |
| Al <sub>2</sub> O <sub>3</sub> | 16.08           | 14.27             | 14.97           | 14.62           | 14.85             | 15.44           | 14.55           | 14.96           |
| Fe <sub>2</sub> O <sub>3</sub> | 2.62            | 3.70              | 3.87            | 3.91            | 4.43              | 4.30            | 3.35            | 3.78            |
| CaO                            | 1.84            | 1.57              | 1.45            | 1.62            | 1.80              | 1.25            | 1.40            | 1.71            |
| MgO                            | 1.13            | 1.49              | 1.48            | 1.47            | 1.68              | 2.01            | 1.44            | 1.53            |
| Na <sub>2</sub> O              | 3.67            | 3.22              | 3.28            | 3.31            | 3.31              | 2.44            | 3.50            | 3.25            |
| K <sub>2</sub> O               | 4.21            | 3.79              | 4.39            | 4.06            | 3.94              | 4.08            | 4.03            | 4.25            |
| TiO <sub>2</sub>               | 0.43            | 0.50              | 0.51            | 0.55            | 0.62              | 0.60            | 0.44            | 0.53            |
| P <sub>2</sub> O <sub>5</sub>  | 0.19            | 0.18              | 0.20            | 0.20            | 0.22              | 0.18            | 0.19            | 0.19            |
| MnO                            | 0.05            | 0.08              | 0.08            | 0.07            | 0.10              | 0.08            | 0.08            | 0.08            |
| H <sub>2</sub> O               | 0.80            | 0.70              | 0.60            | 0.50            | 0.80              | 1.10            | 0.50            | 0.60            |
| Q                              | 26.07           | 31.90             | 28.15           | 30.20           | 28.43             | 33.33           | 29.91           | 28.36           |
| OR                             | 25.29           | 22.74             | 26.32           | 24.04           | 23.48             | 24.61           | 24.08           | 25.41           |
| AB                             | 31.54           | 27.64             | 28.13           | 28.04           | 28.22             | 21.05           | 29.91           | 27.79           |
| AN                             | 8.01            | 6.71              | 5.97            | 6.74            | 7.55              | 5.12            | 5.76            | 7.32            |
| C                              | 2.63            | 2.48              | 2.70            | 2.31            | 2.41              | 5.27            | 2.36            | 2.38            |
| EN                             | 2.86            | 3.76              | 3.74            | 3.67            | 4.22              | 5.11            | 3.62            | 3.85            |
| IL                             | 0.11            | 0.17              | 0.17            | 0.15            | 0.22              | 0.17            | 0.17            | 0.17            |
| HM                             | 2.66            | 3.75              | 3.92            | 3.91            | 4.46              | 4.39            | 3.38            | 3.82            |
| RU                             | 0.38            | 0.42              | 0.43            | 0.47            | 0.51              | 0.52            | 0.35            | 0.44            |
| AP                             | 0.45            | 0.42              | 0.47            | 0.46            | 0.51              | 0.43            | 0.45            | 0.45            |
| A/CNK                          | 1.15            | 1.16              | 1.17            | 1.14            | 1.14              | 1.44            | 1.15            | 1.15            |
| TTDI                           | 82.90           | 82.28             | 82.61           | 82.28           | 80.12             | 79.00           | 83.90           | 81.56           |
| Col. Ind.                      | 5.63            | 7.69              | 7.83            | 7.73            | 8.89              | 9.67            | 7.18            | 7.85            |
| Ba                             | 655             | 372               | 610             | 567             | 541               | 564             | 385             | 602             |
| Rb                             | 142             | 147               | 172             | 149             | 152               | 168             | 178             | 159             |
| Sr                             | 157             | 109               | 116             | 119             | 136               | 133             | 98              | 124             |
| Zr                             | 193             | 170               | 174             | 173             | 197               | 169             | 137             | 180             |
| Nb                             | 10              | 11                | 11              | 11              | 12                | 11              | 11              | 11              |
| V                              | 30              | 39                | 33              | 45              | 54                | 74              | 40              | 50              |
| Y                              | 35              | 38                | 36              | 34              | 32                | 25              | 31              | 33              |
| Ga                             | 19              | 17                | 16              | 17              | 16                | 19              | 16              | 17              |
| Cu                             | 0               | 0                 | 0               | 0               | 0                 | 0               | 0               | 0               |
| Zn                             | 52              | 55                | 57              | 57              | 80                | 73              | 62              | 63              |
| Hf                             | 5               | 4                 | 5               | 5               | 6                 | 4               | 4               | 5               |
| Ta                             | 0.9             | 1.7               | 1.2             | 1.4             | 1.4               | 1.4             | 1.7             | 1.0             |
| Sc                             | 4.3             | 7.5               | 7.7             | 9.0             | 9.3               | 9.3             | 7.7             | 8.9             |
| La                             | 32              | 27                | 27              | 29              | 29                | 33              | 23              | 29              |
| Th                             | 14.0            | 10.0              | 11.0            | 11.0            | 12.0              | 16.0            | 8.9             | 11.0            |
| U                              | 2.3             | 4.0               | 4.5             | 3.3             | 3.7               | 4.0             | 3.7             | 4.1             |
| Li                             | 41              | 60                | 62              | 49              | 65                | 82              | 86              | 57              |
| F                              | 595             | 506               | 617             | 520             | 670               | 777             | 543             | 552             |
| As                             | 1.7             | 2.1               | 2.6             | 2.2             | 6.1               | 3.9             | 2.5             | 2.1             |
| Sn                             | 4               | 3                 | 2               | 0               | 6                 | 4               | 2               | 2               |
| W                              | 0               | 0                 | 0               | 1               | 0                 | 1               | 1               | 0               |

## SGP cont.

| SAMPLE<br>Rock Type            | A12-1008<br>BMG | A12-1010<br>BMG | A12-1020-1<br>BMG | A12-8002-1<br>BMG | A12-8008<br>BMG | A12-8017<br>BMG | A14-1032<br>BMG | A15-0072<br>BMG |
|--------------------------------|-----------------|-----------------|-------------------|-------------------|-----------------|-----------------|-----------------|-----------------|
| SiO <sub>2</sub>               | 67.11           | 68.04           | 67.03             | 65.79             | 66.85           | 69.23           | 69.24           | 66.25           |
| Al <sub>2</sub> O <sub>3</sub> | 15.45           | 15.47           | 15.68             | 15.43             | 15.42           | 14.76           | 14.56           | 15.45           |
| Fe <sub>2</sub> O <sub>3</sub> | 4.25            | 4.31            | 4.27              | 5.75              | 4.85            | 4.13            | 4.37            | 5.11            |
| CaO                            | 1.75            | 1.62            | 2.23              | 2.27              | 2.00            | 1.47            | 1.71            | 2.24            |
| MgO                            | 1.64            | 1.65            | 1.64              | 1.97              | 1.73            | 1.62            | 1.67            | 1.91            |
| Na <sub>2</sub> O              | 3.53            | 3.46            | 3.66              | 3.60              | 3.48            | 2.94            | 2.77            | 3.64            |
| K <sub>2</sub> O               | 4.47            | 4.04            | 4.04              | 3.70              | 3.90            | 4.05            | 3.69            | 3.78            |
| TiO <sub>2</sub>               | 0.61            | 0.62            | 0.65              | 0.82              | 0.73            | 0.60            | 0.62            | 0.77            |
| P <sub>2</sub> O <sub>5</sub>  | 0.22            | 0.21            | 0.20              | 0.23              | 0.23            | 0.18            | 0.24            | 0.22            |
| MnO                            | 0.08            | 0.09            | 0.08              | 0.10              | 0.09            | 0.08            | 0.06            | 0.10            |
| H <sub>2</sub> O               | 0.50            | 0.70            | 0.60              | 0.40              | 0.40            | 0.80            | 0.30            | 0.29            |
| Q                              | 24.09           | 27.23           | 23.73             | 23.66             | 25.64           | 31.86           | 33.88           | 23.70           |
| OR                             | 26.68           | 24.01           | 24.02             | 21.97             | 23.24           | 24.18           | 22.06           | 22.48           |
| AB                             | 30.13           | 29.42           | 31.13             | 30.52             | 29.66           | 25.11           | 23.69           | 30.96           |
| AN                             | 7.31            | 6.70            | 9.80              | 9.77              | 8.48            | 6.17            | 6.99            | 9.72            |
| C                              | 2.17            | 2.97            | 1.72              | 1.95              | 2.40            | 3.33            | 3.51            | 1.83            |
| EN                             | 4.12            | 4.13            | 4.11              | 4.91              | 4.34            | 4.07            | 4.20            | 4.78            |
| IL                             | 0.17            | 0.19            | 0.17              | 0.23              | 0.19            | 0.17            | 0.13            | 0.22            |
| HM                             | 4.29            | 4.33            | 4.29              | 5.77              | 4.89            | 4.17            | 4.42            | 5.14            |
| RU                             | 0.52            | 0.52            | 0.56              | 0.70              | 0.63            | 0.51            | 0.56            | 0.66            |
| AP                             | 0.51            | 0.49            | 0.47              | 0.54              | 0.54            | 0.42            | 0.56            | 0.51            |
| A/CNK                          | 1.12            | 1.19            | 1.09              | 1.10              | 1.14            | 1.24            | 1.25            | 1.09            |
| TTDI                           | 80.91           | 80.67           | 78.88             | 76.15             | 78.53           | 81.15           | 79.63           | 77.14           |
| Col. Ind.                      | 8.58            | 8.65            | 8.57              | 10.90             | 9.42            | 8.41            | 8.75            | 10.13           |
| Ba                             | 818             | 614             | 980               | 830               | 819             | 591             | 561             | 745             |
| Rb                             | 154             | 164             | 132               | 144               | 137             | 162             | 163             | 141             |
| Sr                             | 145             | 134             | 176               | 163               | 159             | 126             | 128             | 170             |
| Zr                             | 198             | 205             | 218               | 258               | 230             | 192             | 190             | 205             |
| Nb                             | 13              | 12              | 13                | 14                | 13              | 13              | 16              | 13              |
| V                              | 50              | 53              | 55                | 80                | 61              | 50              | 50              | 69              |
| Y                              | 38              | 33              | 31                | 38                | 39              | 33              | 38              | 39              |
| Ga                             | 19              | 18              | 18                | 19                | 21              | 20              | 18              | 20              |
| Cu                             | 0               | 0               | 0                 | 0                 | 0               | 0               | 0               | 15              |
| Zn                             | 65              | 61              | 62                | 85                | 71              | 59              | 70              | 75              |
| Hf                             | 6               | 6               | 6                 | 7                 | 7               | 5               | 8               | 8               |
| Ta                             | 1.5             | 1.6             | 1.1               | 1.6               | 1.3             | 1.4             | 1.4             | 1.5             |
| Sc                             | 8.3             | 9.2             | 10.0              | 14.0              | 10.0            | 9.2             | 9.4             | 14.0            |
| La                             | 30              | 32              | 34                | 44                | 34              | 29              | 35              | 15              |
| Th                             | 13.0            | 12.0            | 12.0              | 14.0              | 13.0            | 12.0            | 14.0            | 2.5             |
| U                              | 2.7             | 2.5             | 3.2               | 4.1               | 2.2             | 2.8             | 4.5             | 3.5             |
| Li                             | 40              | 51              | 37                | 66                | 38              | 50              | 58              | 58              |
| F                              | 523             | 473             | 567               | 704               | 570             | 480             | 334             | 625             |
| As                             | 19.0            | 19.0            | 3.0               | 16.0              | 3.5             | 3.4             | 2.7             | 7.5             |
| Sn                             | 3               | 7               | 3                 | 0                 | 0               | 1               | 6               | 6               |
| W                              | 1               | 4               | 0                 | 0                 | 0               | 0               | 1               | 0               |

## SGP cont.

| SAMPLE<br>Rock Type            | A15-0072-2<br>BMG | A15-0072-3<br>BMG | A15-0083<br>BMG | A15-0115<br>BMG | A11-2276-1<br>BMG(p) | A10-3107<br>FGLMG | A10-3107-G<br>FGLMG | A11-2262-2<br>FGLMG |
|--------------------------------|-------------------|-------------------|-----------------|-----------------|----------------------|-------------------|---------------------|---------------------|
| SiO <sub>2</sub>               | 66.73             | 67.42             | 66.89           | 69.28           | 72.74                | 72.64             | 73.21               | 74.14               |
| Al <sub>2</sub> O <sub>3</sub> | 15.11             | 14.91             | 15.32           | 14.73           | 13.65                | 14.21             | 14.12               | 14.60               |
| Fe <sub>2</sub> O <sub>3</sub> | 4.77              | 4.80              | 4.47            | 3.62            | 2.67                 | 1.88              | 1.88                | 1.18                |
| CaO                            | 2.06              | 1.90              | 1.95            | 1.64            | 1.05                 | 0.58              | 0.53                | 0.40                |
| MgO                            | 1.83              | 1.66              | 1.76            | 1.49            | 1.24                 | 0.90              | 0.98                | 0.82                |
| Na <sub>2</sub> O              | 3.47              | 3.32              | 3.33            | 3.24            | 2.98                 | 3.01              | 3.01                | 3.48                |
| K <sub>2</sub> O               | 3.66              | 3.98              | 4.13            | 3.95            | 4.18                 | 5.36              | 5.39                | 4.37                |
| TiO <sub>2</sub>               | 0.71              | 0.72              | 0.65            | 0.52            | 0.32                 | 0.21              | 0.20                | 0.09                |
| P <sub>2</sub> O <sub>5</sub>  | 0.23              | 0.24              | 0.20            | 0.20            | 0.16                 | 0.17              | 0.18                | 0.30                |
| MnO                            | 0.10              | 0.10              | 0.09            | 0.07            | 0.08                 | 0.04              | 0.03                | 0.04                |
| H <sub>2</sub> O               | 0.49              | 0.47              | 0.51            | 0.51            | 0.30                 | 0.44              | 0.51                | 0.70                |
| Q                              | 26.38             | 27.25             | 25.77           | 30.52           | 36.08                | 32.82             | 33.12               | 36.14               |
| OR                             | 21.94             | 23.77             | 24.73           | 23.66           | 24.96                | 32.02             | 32.03               | 26.00               |
| AB                             | 29.75             | 28.36             | 28.52           | 27.76           | 25.45                | 25.72             | 25.59               | 29.62               |
| AN                             | 8.83              | 7.93              | 8.47            | 6.91            | 4.20                 | 1.78              | 1.46                | 0.02                |
| C                              | 2.27              | 2.28              | 2.33            | 2.65            | 2.72                 | 2.83              | 2.81                | 4.16                |
| EN                             | 4.62              | 4.17              | 4.44            | 3.76            | 3.12                 | 2.26              | 2.45                | 2.05                |
| IL                             | 0.22              | 0.22              | 0.19            | 0.15            | 0.17                 | 0.09              | 0.06                | 0.09                |
| HM                             | 4.83              | 4.85              | 4.52            | 3.67            | 2.70                 | 1.90              | 1.89                | 1.19                |
| RU                             | 0.61              | 0.61              | 0.56            | 0.45            | 0.23                 | 0.17              | 0.17                | 0.05                |
| AP                             | 0.54              | 0.56              | 0.47            | 0.47            | 0.37                 | 0.40              | 0.42                | 0.70                |
| A/CNK                          | 1.13              | 1.13              | 1.14            | 1.17            | 1.20                 | 1.20              | 1.20                | 1.31                |
| TTDI                           | 78.08             | 79.38             | 79.02           | 81.94           | 86.49                | 90.57             | 90.74               | 91.75               |
| Col. Ind.                      | 9.67              | 9.24              | 9.16            | 7.58            | 5.98                 | 4.25              | 4.41                | 3.33                |
| Ba                             | 654               | 498               | 692             | 481             | 300                  | 462               | 426                 | 172                 |
| Rb                             | 150               | 162               | 155             | 148             | 189                  | 210               | 215                 | 178                 |
| Sr                             | 167               | 140               | 150             | 131             | 74                   | 76                | 64                  | 38                  |
| Zr                             | 206               | 186               | 194             | 166             | 101                  | 112               | 117                 | 31                  |
| Nb                             | 12                | 12                | 10              | 12              | 7                    | 11                | 11                  | 8                   |
| V                              | 61                | 57                | 54              | 45              | 21                   | 0                 | 10                  | 0                   |
| Y                              | 33                | 50                | 35              | 30              | 31                   | 20                | 19                  | 18                  |
| Ga                             | 16                | 20                | 21              | 18              | 15                   | 17                | 17                  | 15                  |
| Cu                             | 12                | 11                | 11              | 5               | 0                    | 0                 | 5                   | 0                   |
| Zn                             | 75                | 70                | 66              | 59              | 43                   | 38                | 43                  | 30                  |
| Hf                             | 7                 | 7                 | 7               | 6               | 3                    | 4                 | 4                   | 0                   |
| Ta                             | 1.2               | 1.2               | 1.1             | 1.3             | 1.4                  | 1.4               | 1.0                 | 1.7                 |
| Sc                             | 14.0              | 13.0              | 12.0            | 10.0            | 5.6                  | 2.9               | 3.7                 | 2.6                 |
| La                             | 39                | 29                | 37              | 33              | 18                   | 21                | 19                  | 4                   |
| Th                             | 14.0              | 10.0              | 13.0            | 12.0            | 7.3                  | 12.0              | 11.0                | 1.2                 |
| U                              | 3.5               | 2.5               | 4.0             | 3.0             | 2.9                  | 5.1               | 4.3                 | 2.0                 |
| Li                             | 66                | 65                | 52              | 53              | 68                   | 18                | 30                  | 27                  |
| F                              | 690               | 780               | 590             | 570             | 514                  | 470               | 405                 | 269                 |
| As                             | 3.9               | 2.0               | 3.4             | 4.0             | 6.7                  | 23.0              | 6.8                 | 3.2                 |
| Sn                             | 2                 | 2                 | 4               | 0               | 6                    | 7                 | 4                   | 12                  |
| W                              | 0                 | 0                 | 0               | 0               | 0                    | 1                 | 2                   | 2                   |

## SGP cont.

| SAMPLE<br>Rock Type            | A11-2268<br>FGLMG | A11-2272-1<br>FGLMG | A11-2290<br>FGLMG | A12-1010-2<br>FGLMG | A12-1010-4<br>FGLMG | A12-1016<br>FGLMG | A12-1016-1<br>FGLMG | A12-1016-4<br>FGLMG |
|--------------------------------|-------------------|---------------------|-------------------|---------------------|---------------------|-------------------|---------------------|---------------------|
| SiO <sub>2</sub>               | 74.26             | 76.29               | 76.50             | 74.36               | 74.92               | 74.66             | 76.05               | 74.82               |
| Al <sub>2</sub> O <sub>3</sub> | 13.48             | 13.54               | 13.29             | 14.49               | 14.29               | 13.61             | 13.53               | 13.70               |
| Fe <sub>2</sub> O <sub>3</sub> | 2.01              | 0.50                | 0.69              | 0.72                | 0.68                | 2.05              | 1.25                | 1.81                |
| CaO                            | 0.30              | 0.40                | 0.46              | 0.35                | 0.39                | 0.55              | 0.29                | 0.47                |
| MgO                            | 0.97              | 0.68                | 0.70              | 0.78                | 0.78                | 0.90              | 0.80                | 0.82                |
| Na <sub>2</sub> O              | 3.24              | 3.80                | 3.41              | 3.94                | 4.09                | 3.16              | 3.68                | 3.88                |
| K <sub>2</sub> O               | 4.77              | 4.37                | 4.51              | 4.85                | 4.61                | 4.61              | 4.81                | 4.54                |
| TiO <sub>2</sub>               | 0.16              | 0.05                | 0.05              | 0.06                | 0.05                | 0.18              | 0.05                | 0.15                |
| P <sub>2</sub> O <sub>5</sub>  | 0.13              | 0.33                | 0.13              | 0.19                | 0.19                | 0.13              | 0.12                | 0.15                |
| MnO                            | 0.06              | 0.02                | 0.03              | 0.03                | 0.03                | 0.07              | 0.05                | 0.07                |
| H <sub>2</sub> O               | 0.60              | 0.40                | 0.10              | 0.40                | 0.40                | 0.40              | 0.30                | 0.50                |
| Q                              | 35.64             | 36.43               | 37.81             | 31.56               | 32.00               | 36.49             | 34.53               | 32.92               |
| OR                             | 28.39             | 25.84               | 26.74             | 28.75               | 27.26               | 27.29             | 28.27               | 26.74               |
| AB                             | 27.58             | 32.15               | 28.92             | 33.41               | 34.59               | 26.76             | 30.94               | 32.69               |
| AN                             | 0.64              | 0.00                | 1.43              | 0.49                | 0.69                | 1.88              | 0.65                | 1.34                |
| C                              | 2.77              | 2.55                | 2.28              | 2.58                | 2.31                | 2.73              | 2.01                | 1.90                |
| EN                             | 2.43              | 1.69                | 1.75              | 1.95                | 1.94                | 2.24              | 1.98                | 2.03                |
| IL                             | 0.13              | 0.04                | 0.06              | 0.06                | 0.06                | 0.15              | 0.09                | 0.15                |
| HM                             | 2.02              | 0.50                | 0.69              | 0.72                | 0.68                | 2.05              | 1.23                | 1.80                |
| RU                             | 0.09              | 0.03                | 0.02              | 0.03                | 0.02                | 0.10              | 0.00                | 0.07                |
| AP                             | 0.30              | 0.77                | 0.30              | 0.44                | 0.44                | 0.30              | 0.28                | 0.35                |
| A/CNK                          | 1.22              | 1.16                | 1.17              | 1.17                | 1.15                | 1.22              | 1.15                | 1.13                |
| TTDI                           | 91.61             | 94.42               | 93.47             | 93.73               | 93.85               | 90.54             | 93.74               | 92.36               |
| Col. Ind.                      | 4.58              | 2.24                | 2.50              | 2.73                | 2.69                | 4.44              | 3.32                | 3.99                |
| Ba                             | 228               | 39                  | 71                | 144                 | 82                  | 269               | 25                  | 218                 |
| Rb                             | 211               | 239                 | 159               | 173                 | 157                 | 248               | 258                 | 235                 |
| Sr                             | 33                | 11                  | 32                | 37                  | 22                  | 40                | 9                   | 39                  |
| Zr                             | 79                | 12                  | 19                | 38                  | 31                  | 89                | 32                  | 83                  |
| Nb                             | 5                 | 7                   | 0                 | 7                   | 5                   | 8                 | 6                   | 10                  |
| V                              | 9                 | 0                   | 0                 | 0                   | 0                   | 10                | 0                   | 6                   |
| Y                              | 34                | 15                  | 20                | 16                  | 13                  | 35                | 21                  | 31                  |
| Ga                             | 14                | 16                  | 11                | 16                  | 17                  | 18                | 16                  | 18                  |
| Cu                             | 0                 | 0                   | 0                 | 0                   | 0                   | 0                 | 0                   | 0                   |
| Zn                             | 33                | 43                  | 18                | 24                  | 16                  | 39                | 27                  | 30                  |
| Hf                             | 3                 | 0                   | 2                 | 1                   | 1                   | 2                 | 0                   | 2                   |
| Ta                             | 1.3               | 3.9                 | 1.1               | 2.1                 | 1.8                 | 1.5               | 1.5                 | 1.8                 |
| Sc                             | 4.1               | 2.1                 | 1.9               | 1.8                 | 1.6                 | 4.6               | 3.2                 | 4.1                 |
| La                             | 10                | 0                   | 3                 | 3                   | 2                   | 13                | 3                   | 11                  |
| Th                             | 6.1               | 0.0                 | 1.9               | 1.8                 | 1.4                 | 5.9               | 2.4                 | 5.2                 |
| U                              | 3.7               | 3.9                 | 5.7               | 8.7                 | 17.0                | 3.3               | 3.4                 | 7.6                 |
| Li                             | 38                | 10                  | 8                 | 11                  | 8                   | 77                | 38                  | 52                  |
| F                              | 297               | 252                 | 136               | 139                 | 114                 | 434               | 269                 | 264                 |
| As                             | 11.0              | 2.9                 | 7.5               | 38.0                | 46.0                | 6.9               | 4.6                 | 6.8                 |
| Sn                             | 7                 | 16                  | 1                 | 6                   | 5                   | 5                 | 8                   | 5                   |
| W                              | 3                 | 4                   | 2                 | 4                   | 3                   | 3                 | 4                   | 3                   |



## SGP cont.

| SAMPLE<br>Rock Type            | A12-1016-5<br>FGLMG | A12-1016-6<br>FGLMG | A12-1019<br>FGLMG | A12-1019-2<br>FGLMG | A15-0102<br>FGLMG | A15-0103<br>FGLMG | A15-0111<br>FGLMG | A15-0111-2<br>FGLMG |
|--------------------------------|---------------------|---------------------|-------------------|---------------------|-------------------|-------------------|-------------------|---------------------|
| SiO <sub>2</sub>               | 73.59               | 74.57               | 74.23             | 73.60               | 71.76             | 69.77             | 72.51             | 72.55               |
| Al <sub>2</sub> O <sub>3</sub> | 13.99               | 13.61               | 14.38             | 14.18               | 14.52             | 15.25             | 14.86             | 15.03               |
| Fe <sub>2</sub> O <sub>3</sub> | 2.06                | 2.01                | 0.98              | 1.28                | 2.73              | 2.66              | 1.51              | 1.41                |
| CaO                            | 0.81                | 0.50                | 0.50              | 0.48                | 0.86              | 0.80              | 0.44              | 0.48                |
| MgO                            | 0.89                | 0.95                | 0.86              | 0.92                | 1.22              | 1.30              | 0.94              | 0.92                |
| Na <sub>2</sub> O              | 3.61                | 3.16                | 3.70              | 4.12                | 3.36              | 3.10              | 3.29              | 3.07                |
| K <sub>2</sub> O               | 4.46                | 4.70                | 5.28              | 5.06                | 4.19              | 5.16              | 5.23              | 5.22                |
| TiO <sub>2</sub>               | 0.19                | 0.18                | 0.07              | 0.10                | 0.37              | 0.42              | 0.20              | 0.20                |
| P <sub>2</sub> O <sub>5</sub>  | 0.14                | 0.12                | 0.24              | 0.25                | 0.12              | 0.24              | 0.23              | 0.23                |
| MnO                            | 0.08                | 0.07                | 0.04              | 0.05                | 0.08              | 0.04              | 0.03              | 0.04                |
| H <sub>2</sub> O               | 0.20                | 0.70                | 0.40              | 0.30                | 0.68              | 0.73              | 0.95              | 0.74                |
| Q                              | 32.90               | 36.08               | 30.72             | 28.55               | 33.10             | 29.37             | 31.89             | 33.23               |
| OR                             | 26.43               | 27.84               | 31.14             | 29.92               | 24.98             | 30.91             | 31.17             | 31.14               |
| AB                             | 30.60               | 26.77               | 31.22             | 34.84               | 28.65             | 26.56             | 28.05             | 26.20               |
| AN                             | 3.11                | 1.70                | 0.91              | 0.74                | 3.51              | 2.43              | 0.68              | 0.88                |
| C                              | 2.09                | 2.70                | 2.23              | 1.65                | 3.20              | 3.73              | 3.56              | 4.04                |
| EN                             | 2.22                | 2.37                | 2.14              | 2.29                | 3.06              | 3.28              | 2.36              | 2.31                |
| IL                             | 0.17                | 0.15                | 0.09              | 0.11                | 0.17              | 0.09              | 0.06              | 0.09                |
| HM                             | 2.06                | 2.01                | 0.98              | 1.28                | 2.75              | 2.69              | 1.52              | 1.42                |
| RU                             | 0.10                | 0.10                | 0.02              | 0.04                | 0.28              | 0.38              | 0.17              | 0.16                |
| AP                             | 0.33                | 0.28                | 0.56              | 0.58                | 0.28              | 0.56              | 0.54              | 0.54                |
| A/CNK                          | 1.14                | 1.22                | 1.13              | 1.08                | 1.25              | 1.26              | 1.25              | 1.30                |
| TTDI                           | 89.92               | 90.69               | 93.08             | 93.31               | 86.74             | 86.84             | 91.11             | 90.57               |
| Col. Ind.                      | 4.46                | 4.53                | 3.20              | 3.68                | 5.99              | 6.06              | 3.95              | 3.82                |
| Ba                             | 268                 | 273                 | 306               | 292                 | 438               | 558               | 283               | 288                 |
| Rb                             | 230                 | 220                 | 153               | 152                 | 180               | 232               | 289               | 286                 |
| Sr                             | 53                  | 39                  | 97                | 111                 | 97                | 111               | 78                | 87                  |
| Zr                             | 94                  | 88                  | 45                | 58                  | 119               | 154               | 81                | 80                  |
| Nb                             | 9                   | 8                   | 5                 | 6                   | 11                | 13                | 13                | 13                  |
| V                              | 10                  | 8                   | 0                 | 0                   | 23                | 31                | 7                 | 0                   |
| Y                              | 31                  | 29                  | 16                | 21                  | 31                | 22                | 21                | 20                  |
| Ga                             | 17                  | 17                  | 13                | 12                  | 17                | 21                | 19                | 18                  |
| Cu                             | 0                   | 0                   | 0                 | 0                   | 0                 | 8                 | 0                 | 6                   |
| Zn                             | 34                  | 33                  | 21                | 27                  | 58                | 88                | 52                | 60                  |
| Hf                             | 3                   | 3                   | 0                 | 0                   | 4                 | 5                 | 3                 | 3                   |
| Ta                             | 1.8                 | 1.3                 | 0.9               | 0.8                 | 0.7               | 1.3               | 1.5               | 1.6                 |
| Sc                             | 4.5                 | 4.4                 | 1.8               | 3.0                 | 6.4               | 4.7               | 2.1               | 2.0                 |
| La                             | 13                  | 11                  | 4                 | 8                   | 21                | 39                | 23                | 24                  |
| Th                             | 5.9                 | 5.9                 | 1.0               | 1.8                 | 11.0              | 23.8              | 12.0              | 12.0                |
| U                              | 2.9                 | 4.4                 | 1.5               | 1.7                 | 2.9               | 5.0               | 5.4               | 8.1                 |
| Li                             | 94                  | 65                  | 12                | 13                  | 78                | 82                | 84                | 114                 |
| F                              | 501                 | 295                 | 163               | 182                 | 505               | 795               | 510               | 500                 |
| As                             | 5.1                 | 3.6                 | 31.0              | 104.0               | 1.9               | 5.0               | 7.3               | 6.9                 |
| Sn                             | 6                   | 1                   | 2                 | 0                   | 1                 | 6                 | 13                | 10                  |
| W                              | 2                   | 7                   | 3                 | 10                  | 0                 | 2                 | 2                 | 3                   |

## SGP cont.

| SAMPLE<br>Rock Type | A15-0114<br>FGLMG | A11-2257<br>FGLMG(d) | A11-2282<br>MLG(d) |
|---------------------|-------------------|----------------------|--------------------|
| SiO2                | 72.89             | 75.78                | 74.54              |
| Al2O3               | 14.62             | 14.47                | 14.29              |
| Fe2O3               | 1.70              | 0.62                 | 0.93               |
| CaO                 | 0.62              | 0.28                 | 0.33               |
| MgO                 | 1.04              | 0.76                 | 0.79               |
| Na2O                | 3.18              | 3.92                 | 3.96               |
| K2O                 | 4.84              | 3.22                 | 4.58               |
| TiO2                | 0.18              | 0.03                 | 0.08               |
| P2O5                | 0.20              | 0.32                 | 0.22               |
| MnO                 | 0.07              | 0.03                 | 0.03               |
| H2O                 | 0.74              | 0.60                 | 0.60               |
| Q                   | 33.76             | 39.68                | 32.78              |
| OR                  | 28.82             | 19.13                | 27.16              |
| AB                  | 27.08             | 33.31                | 33.59              |
| AN                  | 1.78              | 0.00                 | 0.20               |
| C                   | 3.52              | 4.55                 | 2.75               |
| EN                  | 2.61              | 1.90                 | 1.97               |
| IL                  | 0.15              | 0.06                 | 0.06               |
| HM                  | 1.71              | 0.62                 | 0.93               |
| RU                  | 0.10              | 0.00                 | 0.05               |
| AP                  | 0.47              | 0.75                 | 0.51               |
| A/CNK               | 1.26              | 1.39                 | 1.18               |
| TTDI                | 89.66             | 92.12                | 93.53              |
| Col. Ind.           | 4.47              | 2.58                 | 2.97               |
| Ba                  | 294               | 50                   | 137                |
| Rb                  | 194               | 426                  | 200                |
| Sr                  | 94                | 9                    | 44                 |
| Zr                  | 77                | 8                    | 27                 |
| Nb                  | 10                | 35                   | 8                  |
| V                   | 6                 | 0                    | 0                  |
| Y                   | 23                | 21                   | 18                 |
| Ga                  | 15                | 28                   | 15                 |
| Cu                  | 13                | 0                    | 0                  |
| Zn                  | 44                | 15                   | 50                 |
| Hf                  | 3                 | 1                    | 0                  |
| Ta                  | 1.5               | 11.0                 | 3.0                |
| Sc                  | 3.1               | 1.3                  | 2.2                |
| La                  | 14                | 0                    | 5                  |
| Th                  | 5.9               | 0.5                  | 1.9                |
| U                   | 3.8               | 6.0                  | 7.0                |
| Li                  | 49                | 14                   | 24                 |
| F                   | 230               | 377                  | 262                |
| As                  | 23.0              | 0.6                  | 3.9                |
| Sn                  | 7                 | 20                   | 5                  |
| W                   | 4                 | 9                    | 4                  |

# SALMONTAIL LAKE PLUTON (STP)

| SAMPLE                         | A10-3052 | A15-0049 | A16-1281 | A16-1333 | A10-3004 | A10-3005 | A10-3006 | A10-3009-1 |
|--------------------------------|----------|----------|----------|----------|----------|----------|----------|------------|
| Rock Type                      | MP       | BGD      | BGD      | BGD      | BMG      | BMG      | BMG      | BMG        |
| Major Elements (wt %)          |          |          |          |          |          |          |          |            |
| SiO <sub>2</sub>               | 67.22    | 66.87    | 68.94    | 71.08    | 69.04    | 68.75    | 68.52    | 68.93      |
| Al <sub>2</sub> O <sub>3</sub> | 15.36    | 14.96    | 14.62    | 14.51    | 14.42    | 14.74    | 14.67    | 14.92      |
| Fe <sub>2</sub> O <sub>3</sub> | 4.37     | 5.07     | 3.94     | 2.78     | 4.10     | 4.31     | 4.72     | 3.97       |
| CaO                            | 1.26     | 1.83     | 1.75     | 1.42     | 1.40     | 1.56     | 1.79     | 1.75       |
| MgO                            | 1.78     | 1.77     | 1.82     | 1.31     | 1.51     | 1.52     | 1.66     | 1.55       |
| Na <sub>2</sub> O              | 3.21     | 3.25     | 3.35     | 3.30     | 3.45     | 2.83     | 3.17     | 2.97       |
| K <sub>2</sub> O               | 4.25     | 3.80     | 3.52     | 4.03     | 3.95     | 4.19     | 3.44     | 4.09       |
| TiO <sub>2</sub>               | 0.87     | 0.75     | 0.61     | 0.40     | 0.59     | 0.61     | 0.68     | 0.56       |
| P <sub>2</sub> O <sub>5</sub>  | 0.21     | 0.21     | 0.19     | 0.16     | 0.22     | 0.21     | 0.24     | 0.19       |
| MnO                            | 0.07     | 0.10     | 0.07     | 0.06     | 0.09     | 0.09     | 0.10     | 0.08       |
| H <sub>2</sub> O               | 0.67     | 0.48     | 0.80     | 0.80     | 0.70     | 0.49     | 0.70     | 0.24       |
| Normative Mineralogy           |          |          |          |          |          |          |          |            |
| Q                              | 27.90    | 27.83    | 30.41    | 32.21    | 29.58    | 31.60    | 31.59    | 30.77      |
| OR                             | 25.50    | 22.79    | 21.07    | 24.07    | 23.65    | 25.08    | 20.55    | 24.43      |
| AB                             | 27.54    | 27.88    | 28.68    | 28.19    | 29.55    | 24.23    | 27.09    | 25.38      |
| AN                             | 4.95     | 7.81     | 7.53     | 6.05     | 5.57     | 6.44     | 7.38     | 7.51       |
| C                              | 3.74     | 2.71     | 2.60     | 2.54     | 2.48     | 3.25     | 3.08     | 2.91       |
| EN                             | 4.50     | 4.47     | 4.59     | 3.29     | 3.81     | 3.83     | 4.18     | 3.90       |
| IL                             | 0.15     | 0.22     | 0.15     | 0.13     | 0.19     | 0.19     | 0.22     | 0.17       |
| HM                             | 4.43     | 5.14     | 3.99     | 2.81     | 4.15     | 4.36     | 4.77     | 4.01       |
| RU                             | 0.80     | 0.65     | 0.54     | 0.34     | 0.49     | 0.51     | 0.57     | 0.47       |
| AP                             | 0.49     | 0.49     | 0.45     | 0.37     | 0.52     | 0.49     | 0.56     | 0.45       |
| A/CNK                          | 1.26     | 1.17     | 1.17     | 1.17     | 1.15     | 1.23     | 1.20     | 1.19       |
| TTDI                           | 80.94    | 78.51    | 80.16    | 84.46    | 82.78    | 80.91    | 79.24    | 80.58      |
| Col. Ind.                      | 9.08     | 9.83     | 8.73     | 6.23     | 8.15     | 8.39     | 9.16     | 8.08       |
| Trace Elements (ppm*)          |          |          |          |          |          |          |          |            |
| Ba                             | 888      | 610      | 525      | 504      | 511      | 547      | 496      | 552        |
| Rb                             | 153      | 160      | 143      | 142      | 157      | 164      | 154      | 158        |
| Sr                             | 132      | 147      | 127      | 122      | 138      | 127      | 132      | 126        |
| Zr                             | 222      | 211      | 182      | 128      | 197      | 185      | 216      | 165        |
| Nb                             | 9        | 12       | 15       | 10       | 13       | 11       | 13       | 11         |
| V                              | 69       | 58       | 53       | 31       | 41       | 16       | 54       | 42         |
| Y                              | 32       | 40       | 30       | 24       | 32       | 35       | 34       | 34         |
| Ga                             | 19       | 18       | 21       | 19       | 20       | 16       | 26       | 16         |
| Cu                             | 8        | 11       | 1        | 3        | 6        | 8        | 0        | 8          |
| Zn                             | 70       | 79       | 88       | 51       | 72       | 60       | 77       | 58         |
| Hf                             | 6        | 6        | 7        | 4        | 6        | 6        | 7        | 6          |
| Ta                             | 1.1      | 1.4      | 1.2      | 0.9      | 12.0     | 1.5      | 0.8      | 1.0        |
| Sc                             | 9.4      | 13.0     | 8.9      | 6.1      | 9.4      | 11.0     | 10.0     | 10.0       |
| La                             | 38       | 37       | 34       | 24       | 32       | 32       | 33       | 30         |
| Th                             | 16.0     | 14.0     | 12.0     | 8.8      | 12.0     | 12.0     | 12.0     | 11.0       |
| U                              | 4.1      | 3.8      | 2.2      | 1.9      | 3.0      | 4.7      | 3.6      | 3.7        |
| Li                             | 31       | 72       | 74       | 65       | 88       | 79       | 94       | 40         |
| F                              | 660      | 690      | 660      | 400      | 620      | 575      | 700      | 535        |
| As                             | 8.2      | 2.3      | 4.7      | 5.6      | 4.2      | 10.0     | 2.9      | 8.4        |
| Sn                             | 2        | 4        | 2        | 7        | 11       | 5        | 6        | 1          |
| W                              | 0        | 0        | 1        | 2        | 1        | 1        | 1        | 0          |

## STP cont.

| SAMPLE<br>Rock Type            | A10-3014<br>BMG | A15-0019<br>BMG | A15-0057<br>BMG | A15-0074<br>BMG | A15-0075-A<br>BMG | A15-0148<br>BMG | A15-1307<br>BMG | A15-1318<br>BMG |
|--------------------------------|-----------------|-----------------|-----------------|-----------------|-------------------|-----------------|-----------------|-----------------|
| SiO <sub>2</sub>               | 68.25           | 69.48           | 66.66           | 67.10           | 65.23             | 67.39           | 69.73           | 68.28           |
| Al <sub>2</sub> O <sub>3</sub> | 14.98           | 14.97           | 15.05           | 14.84           | 15.29             | 15.54           | 14.44           | 14.81           |
| Fe <sub>2</sub> O <sub>3</sub> | 4.29            | 3.53            | 5.19            | 4.89            | 5.54              | 4.33            | 3.48            | 4.12            |
| CaO                            | 1.70            | 1.35            | 2.02            | 1.90            | 2.09              | 1.72            | 0.44            | 1.51            |
| MgO                            | 1.53            | 1.51            | 1.88            | 1.69            | 1.98              | 1.47            | 1.15            | 1.49            |
| Na <sub>2</sub> O              | 3.87            | 3.40            | 2.87            | 3.08            | 3.39              | 3.07            | 4.49            | 3.97            |
| K <sub>2</sub> O               | 3.98            | 4.10            | 3.92            | 3.88            | 3.76              | 4.18            | 3.61            | 3.86            |
| TiO <sub>2</sub>               | 0.62            | 0.47            | 0.75            | 0.71            | 0.85              | 0.63            | 0.49            | 0.57            |
| P <sub>2</sub> O <sub>5</sub>  | 0.24            | 0.21            | 0.23            | 0.21            | 0.37              | 0.23            | 0.22            | 0.22            |
| MnO                            | 0.08            | 0.09            | 0.10            | 0.10            | 0.07              | 0.10            | 0.09            | 0.09            |
| H <sub>2</sub> O               | 0.50            | 0.60            | 0.48            | 0.41            | 0.60              | 0.50            | 1.11            | 0.76            |
| Q                              | 25.36           | 29.71           | 28.85           | 28.78           | 25.08             | 28.68           | 28.28           | 25.85           |
| OR                             | 23.65           | 24.47           | 23.50           | 23.32           | 22.56             | 25.06           | 21.76           | 23.08           |
| AB                             | 32.89           | 29.02           | 24.61           | 26.48           | 29.10             | 26.33           | 38.71           | 33.96           |
| AN                             | 6.89            | 5.37            | 8.63            | 8.18            | 8.06              | 7.12            | 0.76            | 6.12            |
| C                              | 1.80            | 3.01            | 3.00            | 2.66            | 2.77              | 3.43            | 2.93            | 1.90            |
| EN                             | 3.83            | 3.79            | 4.74            | 4.28            | 5.00              | 3.71            | 2.92            | 3.75            |
| IL                             | 0.17            | 0.19            | 0.22            | 0.22            | 0.15              | 0.22            | 0.20            | 0.19            |
| HM                             | 4.31            | 3.56            | 5.26            | 4.97            | 5.62              | 4.39            | 3.55            | 4.16            |
| RU                             | 0.53            | 0.37            | 0.65            | 0.61            | 0.78              | 0.52            | 0.40            | 0.47            |
| AP                             | 0.56            | 0.49            | 0.54            | 0.50            | 0.87              | 0.54            | 0.52            | 0.52            |
| A/CNK                          | 1.09            | 1.20            | 1.19            | 1.17            | 1.14              | 1.22            | 1.19            | 1.10            |
| TTDI                           | 81.91           | 83.20           | 76.96           | 78.59           | 76.74             | 80.06           | 88.74           | 82.88           |
| Col. Ind.                      | 8.31            | 7.55            | 10.22           | 9.46            | 10.77             | 8.32            | 6.66            | 8.11            |
| Ba                             | 569             | 472             | 681             | 610             | 616               | 623             | 444             | 487             |
| Rb                             | 160             | 183             | 155             | 157             | 165               | 167             | 132             | 160             |
| Sr                             | 141             | 131             | 156             | 149             | 159               | 137             | 99              | 136             |
| Zr                             | 193             | 158             | 216             | 210             | 247               | 195             | 160             | 193             |
| Nb                             | 12              | 11              | 13              | 12              | 18                | 12              | 11              | 12              |
| V                              | 45              | 36              | 64              | 57              | 65                | 44              | 39              | 51              |
| Y                              | 29              | 26              | 41              | 39              | 39                | 30              | 31              | 40              |
| Ga                             | 21              | 22              | 20              | 15              | 24                | 25              | 18              | 19              |
| Cu                             | 0               | 0               | 16              | 10              | 9                 | 0               | 10              | 11              |
| Zn                             | 75              | 72              | 76              | 67              | 101               | 78              | 65              | 65              |
| Hf                             | 6               | 6               | 7               | 7               | 8                 | 6               | 5               | 6               |
| Ta                             | 1.6             | 1.2             | 1.1             | 1.4             | 1.6               | 1.6             | 1.2             | 1.2             |
| Sc                             | 9.3             | 7.9             | 14.0            | 13.0            | 14.0              | 11.0            | 9.2             | 11.0            |
| La                             | 30              | 26              | 38              | 38              | 41                | 34              | 25              | 31              |
| Th                             | 11.0            | 10.0            | 13.0            | 13.0            | 14.0              | 12.0            | 10.0            | 11.0            |
| U                              | 2.9             | 3.5             | 2.4             | 3.0             | 3.2               | 3.7             | 6.4             | 2.7             |
| Li                             | 113             | 100             | 82              | 66              | 65                | 99              | 44              | 90              |
| F                              | 645             | 660             | 865             | 690             | 715               | 720             | 345             | 635             |
| As                             | 2.6             | 3.3             | 3.5             | 12.0            | 3.6               | 1.8             | 20.0            | 3.2             |
| Sn                             | 9               | 6               | 4               | 2               | 5                 | 8               | 8               | 1               |
| W                              | 2               | 2               | 1               | 0               | 0                 | 1               | 0               | 0               |

## STP cont.

| SAMPLE<br>Rock Type            | A15-1320<br>BMG | A15-1327<br>BMG | A15-1328<br>BMG | A16-1202-C<br>BMG | A16-1202-D<br>BMG | A16-1206<br>BMG | A16-1207-7<br>BMG | A16-1208-A<br>BMG |
|--------------------------------|-----------------|-----------------|-----------------|-------------------|-------------------|-----------------|-------------------|-------------------|
| SiO <sub>2</sub>               | 70.36           | 70.37           | 69.80           | 69.76             | 70.14             | 68.97           | 69.05             | 68.29             |
| Al <sub>2</sub> O <sub>3</sub> | 14.65           | 14.37           | 14.12           | 14.76             | 14.56             | 15.08           | 14.56             | 15.41             |
| Fe <sub>2</sub> O <sub>3</sub> | 2.98            | 3.30            | 4.04            | 3.38              | 3.26              | 3.31            | 3.87              | 3.78              |
| CaO                            | 1.01            | 1.12            | 1.72            | 1.47              | 1.29              | 1.23            | 1.08              | 1.28              |
| MgO                            | 1.26            | 1.41            | 1.68            | 1.42              | 1.41              | 1.41            | 1.45              | 1.55              |
| Na <sub>2</sub> O              | 3.66            | 3.21            | 3.22            | 3.52              | 3.35              | 3.50            | 3.63              | 3.10              |
| K <sub>2</sub> O               | 4.24            | 4.05            | 3.40            | 3.90              | 4.12              | 4.30            | 4.22              | 4.15              |
| TiO <sub>2</sub>               | 0.39            | 0.49            | 0.61            | 0.49              | 0.45              | 0.48            | 0.52              | 0.54              |
| P <sub>2</sub> O <sub>5</sub>  | 0.25            | 0.24            | 0.20            | 0.20              | 0.21              | 0.22            | 0.22              | 0.22              |
| MnO                            | 0.08            | 0.09            | 0.08            | 0.08              | 0.07              | 0.09            | 0.08              | 0.08              |
| H <sub>2</sub> O               | 0.65            | 0.60            | 0.60            | 0.70              | 0.60              | 0.70            | 0.75              | 0.80              |
| Q                              | 29.83           | 32.80           | 32.79           | 29.95             | 30.95             | 28.42           | 28.29             | 30.42             |
| OR                             | 25.36           | 24.28           | 20.34           | 23.31             | 24.65             | 25.80           | 25.30             | 24.95             |
| AB                             | 31.32           | 27.53           | 27.55           | 30.09             | 28.67             | 30.04           | 31.12             | 26.65             |
| AN                             | 3.41            | 4.04            | 7.31            | 6.05              | 5.08              | 4.73            | 3.97              | 4.99              |
| C                              | 2.83            | 3.29            | 2.52            | 2.58              | 2.78              | 3.00            | 2.62              | 4.08              |
| EN                             | 3.17            | 3.56            | 4.23            | 3.57              | 3.55              | 3.56            | 3.66              | 3.92              |
| IL                             | 0.17            | 0.20            | 0.17            | 0.17              | 0.15              | 0.20            | 0.17              | 0.17              |
| HM                             | 3.01            | 3.35            | 4.09            | 3.41              | 3.30              | 3.36            | 3.92              | 3.84              |
| RU                             | 0.30            | 0.39            | 0.53            | 0.40              | 0.38              | 0.38            | 0.44              | 0.46              |
| AP                             | 0.59            | 0.56            | 0.47            | 0.47              | 0.49              | 0.52            | 0.52              | 0.52              |
| A/CNK                          | 1.18            | 1.23            | 1.17            | 1.16              | 1.18              | 1.19            | 1.16              | 1.29              |
| TTDi                           | 86.51           | 84.62           | 80.69           | 83.34             | 84.27             | 84.26           | 84.71             | 82.02             |
| Col. Ind.                      | 6.36            | 7.10            | 8.49            | 7.16              | 7.00              | 7.11            | 7.75              | 7.94              |
| Ba                             | 381             | 419             | 538             | 504               | 459               | 445             | 468               | 486               |
| Rb                             | 196             | 173             | 139             | 173               | 169               | 185             | 183               | 174               |
| Sr                             | 93              | 102             | 133             | 106               | 104               | 104             | 96                | 103               |
| Zr                             | 135             | 166             | 210             | 155               | 148               | 161             | 177               | 175               |
| Nb                             | 11              | 11              | 15              | 12                | 12                | 14              | 11                | 14                |
| V                              | 25              | 31              | 48              | 36                | 36                | 32              | 35                | 35                |
| Y                              | 27              | 28              | 28              | 28                | 27                | 27              | 35                | 30                |
| Ga                             | 18              | 18              | 20              | 18                | 19                | 23              | 18                | 19                |
| Cu                             | 0               | 0               | 0               | 5                 | 0                 | 0               | 15                | 0                 |
| Zn                             | 47              | 55              | 85              | 82                | 72                | 88              | 95                | 63                |
| Hf                             | 4               | 6               | 8               | 5                 | 5                 | 5               | 6                 | 6                 |
| Ta                             | 1.5             | 1.3             | 1.0             | 0.9               | 1.2               | 0.8             | 1.2               | 0.8               |
| Sc                             | 7.7             | 8.4             | 8.8             | 7.8               | 7.5               | 8.2             | 10.0              | 8.7               |
| La                             | 22              | 30              | 36              | 28                | 25                | 27              | 29                | 32                |
| Th                             | 8.6             | 11.0            | 13.0            | 10.0              | 10.0              | 11.0            | 12.0              | 11.0              |
| U                              | 2.8             | 4.3             | 3.0             | 3.0               | 4.7               | 5.4             | 3.2               | 4.2               |
| Li                             | 94              | 105             | 83              | 95                | 98                | 110             | 88                | 118               |
| F                              | 625             | 530             | 720             | 530               | 580               | 630             | 650               | 560               |
| As                             | 13.0            | 7.6             | 6.1             | 3.9               | 2.8               | 2.4             | 7.1               | 2.1               |
| Sn                             | 4               | 10              | 10              | 4                 | 9                 | 10              | 6                 | 11                |
| W                              | 3               | 1               | 1               | 1                 | 1                 | 2               | 0                 | 1                 |



## STP cont.

| SAMPLE<br>Rock Type            | A16-1232<br>BMG | A16-1251-2<br>BMG | A16-1252<br>BMG | A16-1255-2<br>BMG | A16-1268-1<br>BMG | A16-1269-1<br>BMG | A16-1276<br>BMG | A16-1278<br>BMG |
|--------------------------------|-----------------|-------------------|-----------------|-------------------|-------------------|-------------------|-----------------|-----------------|
| SiO <sub>2</sub>               | 69.89           | 68.16             | 69.07           | 66.49             | 67.45             | 68.95             | 69.12           | 67.37           |
| Al <sub>2</sub> O <sub>3</sub> | 14.69           | 15.53             | 14.44           | 15.34             | 14.74             | 14.53             | 14.84           | 15.38           |
| Fe <sub>2</sub> O <sub>3</sub> | 2.87            | 3.71              | 4.20            | 4.59              | 4.93              | 4.16              | 3.67            | 3.73            |
| CaO                            | 1.07            | 1.60              | 1.27            | 1.54              | 1.83              | 1.49              | 1.34            | 1.62            |
| MgO                            | 1.41            | 1.48              | 1.71            | 1.74              | 1.56              | 1.47              | 1.49            | 1.52            |
| Na <sub>2</sub> O              | 3.52            | 3.16              | 3.53            | 3.67              | 3.47              | 3.77              | 3.09            | 3.73            |
| K <sub>2</sub> O               | 4.25            | 4.19              | 3.72            | 3.83              | 3.89              | 3.88              | 4.05            | 4.22            |
| TiO <sub>2</sub>               | 0.40            | 0.55              | 0.59            | 0.67              | 0.69              | 0.57              | 0.53            | 0.53            |
| P <sub>2</sub> O <sub>5</sub>  | 0.23            | 0.23              | 0.21            | 0.21              | 0.23              | 0.21              | 0.22            | 0.21            |
| MnO                            | 0.08            | 0.08              | 0.09            | 0.08              | 0.10              | 0.09              | 0.09            | 0.07            |
| H <sub>2</sub> O               | 0.70            | 0.50              | 0.98            | 0.47              | 0.32              | 0.51              | 0.50            | 0.44            |
| Q                              | 29.86           | 29.12             | 29.96           | 25.64             | 27.07             | 27.61             | 31.65           | 24.77           |
| OR                             | 25.54           | 25.11             | 22.26           | 23.08             | 23.27             | 23.15             | 24.34           | 25.37           |
| AB                             | 30.26           | 27.09             | 30.22           | 31.63             | 29.69             | 32.18             | 26.56           | 32.08           |
| AN                             | 3.86            | 6.52              | 4.98            | 6.38              | 7.66              | 6.07              | 5.29            | 6.77            |
| C                              | 2.95            | 3.48              | 2.83            | 2.91              | 2.07              | 1.94              | 3.52            | 2.27            |
| EN                             | 3.57            | 3.73              | 4.31            | 4.41              | 3.93              | 3.69              | 3.77            | 3.85            |
| IL                             | 0.17            | 0.17              | 0.19            | 0.17              | 0.22              | 0.19              | 0.20            | 0.15            |
| HM                             | 2.92            | 3.76              | 4.25            | 4.68              | 4.99              | 4.20              | 3.73            | 3.79            |
| RU                             | 0.31            | 0.47              | 0.49            | 0.59              | 0.58              | 0.47              | 0.44            | 0.46            |
| AP                             | 0.54            | 0.54              | 0.49            | 0.50              | 0.54              | 0.49              | 0.52            | 0.50            |
| A/CNK                          | 1.19            | 1.23              | 1.19            | 1.18              | 1.11              | 1.11              | 1.25            | 1.13            |
| TTDI                           | 85.67           | 81.33             | 82.44           | 80.35             | 80.02             | 82.94             | 82.55           | 82.22           |
| Col. Ind.                      | 6.66            | 7.67              | 8.75            | 9.26              | 9.13              | 8.08              | 7.69            | 7.79            |
| Ba                             | 469             | 524               | 469             | 709               | 616               | 533               | 397             | 651             |
| Rb                             | 177             | 169               | 162             | 149               | 156               | 160               | 175             | 162             |
| Sr                             | 88              | 120               | 124             | 140               | 148               | 125               | 106             | 135             |
| Zr                             | 129             | 175               | 183             | 226               | 226               | 194               | 176             | 163             |
| Nb                             | 12              | 12                | 11              | 13                | 12                | 11                | 12              | 11              |
| V                              | 25              | 50                | 44              | 54                | 56                | 43                | 41              | 42              |
| Y                              | 24              | 30                | 36              | 35                | 41                | 38                | 29              | 35              |
| Ga                             | 19              | 24                | 18              | 21                | 17                | 18                | 23              | 21              |
| Cu                             | 3               | 0                 | 12              | 6                 | 19                | 7                 | 0               | 7               |
| Zn                             | 55              | 65                | 86              | 85                | 70                | 64                | 101             | 68              |
| Hf                             | 5               | 6                 | 7               | 8                 | 8                 | 7                 | 5               | 5               |
| Ta                             | 2.9             | 1.3               | 1.0             | 1.2               | 1.2               | 1.5               | 8.3             | 1.0             |
| Sc                             | 6.7             | 8.2               | 11.0            | 12.0              | 14.0              | 12.0              | 8.3             | 9.0             |
| La                             | 21              | 30                | 32              | 39                | 41                | 36                | 30              | 30              |
| Th                             | 8.3             | 12.0              | 13.0            | 15.0              | 15.0              | 14.0              | 11.0            | 12.0            |
| U                              | 3.1             | 2.5               | 2.9             | 2.6               | 5.3               | 3.9               | 3.1             | 4.2             |
| Li                             | 133             | 98                | 80              | 84                | 65                | 70                | 102             | 80              |
| F                              | 510             | 560               | 500             | 495               | 610               | 495               | 690             | 475             |
| As                             | 2.0             | 3.8               | 1.7             | 2.3               | 2.1               | 14.0              | 10.0            | 3.7             |
| Sn                             | 12              | 8                 | 4               | 2                 | 4                 | 8                 | 10              | 2               |
| W                              | 1               | 1                 | 2               | 0                 | 0                 | 0                 | 1               | 0               |

## STP cont.

| SAMPLE<br>Rock Type            | A16-1279-3<br>BMG | A16-1287-1<br>BMG | A10-3012<br>FGLMG | A16-1245-2<br>FGLMG | A16-1277-1<br>FGLMG | A16-1299<br>FGLMG | A16-1302<br>FGLMG |
|--------------------------------|-------------------|-------------------|-------------------|---------------------|---------------------|-------------------|-------------------|
| SiO <sub>2</sub>               | 68.54             | 68.72             | 74.00             | 71.63               | 72.45               | 73.18             | 72.01             |
| Al <sub>2</sub> O <sub>3</sub> | 15.37             | 14.85             | 14.52             | 14.58               | 14.57               | 14.95             | 15.02             |
| Fe <sub>2</sub> O <sub>3</sub> | 2.97              | 3.86              | 1.10              | 1.37                | 1.51                | 1.29              | 1.19              |
| CaO                            | 1.36              | 1.22              | 0.40              | 0.42                | 0.65                | 0.36              | 0.36              |
| MgO                            | 1.22              | 1.38              | 0.81              | 0.95                | 1.05                | 1.06              | 0.78              |
| Na <sub>2</sub> O              | 3.90              | 3.63              | 3.67              | 3.59                | 3.31                | 3.31              | 4.15              |
| K <sub>2</sub> O               | 4.84              | 4.27              | 4.39              | 4.56                | 5.06                | 4.69              | 4.88              |
| TiO <sub>2</sub>               | 0.41              | 0.54              | 0.09              | 0.17                | 0.21                | 0.17              | 0.16              |
| P <sub>2</sub> O <sub>5</sub>  | 0.18              | 0.22              | 0.30              | 0.31                | 0.14                | 0.30              | 0.34              |
| MnO                            | 0.07              | 0.09              | 0.04              | 0.04                | 0.03                | 0.03              | 0.04              |
| H <sub>2</sub> O               | 0.57              | 0.82              | 0.40              | 0.80                | 0.53                | 0.50              | 0.75              |
| Q                              | 23.38             | 27.53             | 34.86             | 32.62               | 31.57               | 34.60             | 28.29             |
| OR                             | 28.96             | 25.57             | 26.14             | 27.63               | 30.24               | 27.92             | 29.15             |
| AB                             | 33.38             | 31.09             | 31.26             | 31.11               | 28.29               | 28.18             | 35.46             |
| AN                             | 5.63              | 4.67              | 0.02              | 0.06                | 2.33                | 0.00              | 0.00              |
| C                              | 1.69              | 2.59              | 3.74              | 3.81                | 2.83                | 4.45              | 2.94              |
| EN                             | 3.07              | 3.48              | 2.03              | 2.42                | 2.64                | 2.66              | 1.96              |
| IL                             | 0.15              | 0.19              | 0.09              | 0.09                | 0.06                | 0.06              | 0.09              |
| HM                             | 3.00              | 3.91              | 1.11              | 1.40                | 1.53                | 1.30              | 1.20              |
| RU                             | 0.33              | 0.44              | 0.05              | 0.13                | 0.18                | 0.14              | 0.12              |
| AP                             | 0.42              | 0.52              | 0.70              | 0.74                | 0.33                | 0.70              | 0.80              |
| A/CNK                          | 1.09              | 1.16              | 1.26              | 1.26                | 1.20                | 1.34              | 1.18              |
| TTDI                           | 85.69             | 84.19             | 92.26             | 91.36               | 90.10               | 90.69             | 92.90             |
| Col. Ind.                      | 6.23              | 7.58              | 3.22              | 3.91                | 4.23                | 4.02              | 3.25              |
| Ba                             | 606               | 476               | 207               | 330                 | 537                 | 435               | 503               |
| Rb                             | 157               | 179               | 187               | 202                 | 248                 | 191               | 199               |
| Sr                             | 112               | 127               | 54                | 44                  | 71                  | 44                | 48                |
| Zr                             | 129               | 181               | 40                | 64                  | 122                 | 64                | 63                |
| Nb                             | 8                 | 10                | 10                | 8                   | 10                  | 9                 | 10                |
| V                              | 43                | 37                | 5                 | 10                  | 7                   | 5                 | 0                 |
| Y                              | 31                | 36                | 14                | 18                  | 33                  | 17                | 21                |
| Ga                             | 19                | 17                | 19                | 22                  | 17                  | 21                | 16                |
| Cu                             | 0                 | 8                 | 0                 | 0                   | 0                   | 0                 | 0                 |
| Zn                             | 81                | 63                | 78                | 35                  | 39                  | 38                | 23                |
| Hf                             | 4                 | 6                 | 1                 | 1                   | 4                   | 2                 | 3                 |
| Ta                             | 0.9               | 1.2               | 2.4               | 1.2                 | 1.5                 | 1.2               | 1.6               |
| Sc                             | 6.6               | 10.0              | 4.5               | 4.3                 | 4.2                 | 3.4               | 4.0               |
| La                             | 21                | 28                | 5                 | 8                   | 36                  | 9                 | 9                 |
| Th                             | 10.0              | 12.0              | 1.2               | 4.4                 | 20.7                | 4.8               | 5.2               |
| U                              | 3.8               | 2.9               | 1.5               | 5.9                 | 6.4                 | 5.7               | 7.9               |
| Li                             | 52                | 73                | 34                | 160                 | 96                  | 68                | 49                |
| F                              | 335               | 470               | 210               | 420                 | 305                 | 350               | 105               |
| As                             | 3.3               | 3.3               | 4.1               | 1.9                 | 6.1                 | 9.4               | 5.0               |
| Sn                             | 2                 | 3                 | 12                | 13                  | 13                  | 16                | 11                |
| W                              | 0                 | 2                 | 5                 | 3                   | 2                   | 3                 | 6                 |

# BIG INDIAN LAKE PLUTON (BIP)

| SAMPLE UNIT                    | D13-2090-4<br>MBMG | D13-2126<br>MBMG | A16-1159<br>CGLMG | A16-3016<br>CGLMG | D13-2048<br>CGLMG | D13-2049<br>CGLMG | D13-2060-1<br>CGLMG | D13-2090-2<br>CGLMG |
|--------------------------------|--------------------|------------------|-------------------|-------------------|-------------------|-------------------|---------------------|---------------------|
| Major Elements (wt %)          |                    |                  |                   |                   |                   |                   |                     |                     |
| SiO <sub>2</sub>               | 71.06              | 73.25            | 74.89             | 75.85             | 73.20             | 73.38             | 73.70               | 73.91               |
| Al <sub>2</sub> O <sub>3</sub> | 14.82              | 13.86            | 13.08             | 13.83             | 14.38             | 14.18             | 14.47               | 13.79               |
| Fe <sub>2</sub> O <sub>3</sub> | 2.79               | 2.63             | 1.10              | 0.75              | 1.88              | 1.99              | 1.56                | 1.65                |
| CaO                            | 0.76               | 0.69             | 0.45              | 0.32              | 0.41              | 0.38              | 0.40                | 0.64                |
| MgO                            | 1.44               | 1.35             | 0.86              | 0.64              | 0.95              | 0.94              | 0.84                | 1.10                |
| Na <sub>2</sub> O              | 3.31               | 3.50             | 3.66              | 3.53              | 3.05              | 3.35              | 4.05                | 3.27                |
| K <sub>2</sub> O               | 4.71               | 4.50             | 4.72              | 4.89              | 4.65              | 4.41              | 3.85                | 4.51                |
| TiO <sub>2</sub>               | 0.39               | 0.32             | 0.09              | 0.02              | 0.18              | 0.22              | 0.14                | 0.17                |
| P <sub>2</sub> O <sub>5</sub>  | 0.17               | 0.12             | 0.09              | 0.12              | 0.32              | 0.27              | 0.27                | 0.14                |
| MnO                            | 0.09               | 0.08             | 0.05              | 0.04              | 0.08              | 0.08              | 0.08                | 0.05                |
| H <sub>2</sub> O               | 1.00               | 0.50             | 1.30              | 0.40              | 1.00              | 0.90              | 0.60                | 0.60                |
| Normative Mineralogy           |                    |                  |                   |                   |                   |                   |                     |                     |
| Q                              | 30.61              | 32.40            | 33.87             | 35.29             | 36.55             | 35.83             | 34.27               | 35.27               |
| OR                             | 27.99              | 26.54            | 28.20             | 28.93             | 27.75             | 26.30             | 22.92               | 26.88               |
| AB                             | 28.13              | 29.52            | 31.28             | 29.87             | 26.04             | 28.57             | 34.49               | 27.88               |
| AN                             | 2.67               | 2.63             | 1.66              | 0.80              | 0.00              | 0.12              | 0.22                | 2.28                |
| C                              | 3.31               | 2.25             | 1.36              | 2.43              | 4.36              | 3.88              | 3.58                | 2.72                |
| EN                             | 3.60               | 3.35             | 2.16              | 1.59              | 2.39              | 2.36              | 2.11                | 2.76                |
| IL                             | 0.19               | 0.17             | 0.11              | 0.04              | 0.17              | 0.17              | 0.17                | 0.11                |
| HM                             | 2.80               | 2.62             | 1.11              | 0.70              | 1.90              | 2.01              | 1.57                | 1.66                |
| RU                             | 0.29               | 0.23             | 0.03              | 0.00              | 0.09              | 0.13              | 0.05                | 0.11                |
| AP                             | 0.40               | 0.28             | 0.21              | 0.28              | 0.75              | 0.73              | 0.63                | 0.33                |
| A/CNK                          | 1.24               | 1.17             | 1.09              | 1.18              | 1.33              | 1.29              | 1.25                | 1.21                |
| TTDI                           | 86.73              | 88.46            | 93.35             | 94.08             | 90.34             | 90.70             | 91.67               | 90.03               |
| Col. Ind.                      | 6.60               | 6.14             | 3.38              | 2.40              | 4.46              | 4.54              | 3.85                | 4.53                |
| Trace Elements (ppm*)          |                    |                  |                   |                   |                   |                   |                     |                     |
| Ba                             | 502                | 304              | 76                | 5                 | 236               | 230               | 133                 | 189                 |
| Rb                             | 201                | 178              | 182               | 175               | 243               | 241               | 260                 | 160                 |
| Sr                             | 119                | 72               | 22                | 5                 | 40                | 41                | 26                  | 55                  |
| Zr                             | 137                | 113              | 40                | 26                | 70                | 71                | 52                  | 66                  |
| Nb                             | 10                 | 9                | 6                 | 4                 | 12                | 12                | 12                  | 8                   |
| V                              | 22                 | 21               | 4                 | 0                 | 12                | 16                | 10                  | 9                   |
| Y                              | 25                 | 29               | 19                | 11                | 17                | 15                | 18                  | 16                  |
| Ga                             | 23                 | 19               | 19                | 18                | 19                | 18                | 18                  | 16                  |
| Cu                             | 0                  | 0                | 0                 | 0                 | 0                 | 0                 | 0                   | 0                   |
| Zn                             | 56                 | 42               | 27                | 17                | 64                | 60                | 34                  | 34                  |
| Hf                             | 5                  | 4                | 2                 | 1                 | 2                 | 3                 | 2                   | 2                   |
| Ta                             | 1.0                | 1.0              | 0.9               | 0.5               | 3.0               | 3.3               | 3.1                 | 0.8                 |
| Sc                             | 6.3                | 6.4              | 2.4               | 0.5               | 3.9               | 4.3               | 4.6                 | 3.6                 |
| La                             | 30                 | 20               | 6                 | 2                 | 12                | 14                | 10                  | 9                   |
| Th                             | 15.0               | 8.9              | 4.0               | 0.8               | 5.3               | 7.2               | 5.0                 | 5.4                 |
| U                              | 4.1                | 3.6              | 2.3               | 1.6               | 4.9               | 5.0               | 10.0                | 3.1                 |
| Li                             | 53                 | 41               | 76                | 25                | 59                | 57                | 68                  | 39                  |
| F                              | 470                | 470              | 280               | 92                | 420               | 350               | 500                 | 230                 |
| As                             | 0.9                | 0.7              | 1.2               | 2.0               | 10.0              | 1.3               | 2.6                 | 0.7                 |
| Sn                             | 8                  | 10               | 5                 | 6                 | 12                | 15                | 12                  | 8                   |
| W                              | 3                  | 1                | 1                 | 1                 | 1                 | 2                 | 1                   | 1                   |

## BIP cont.

| SAMPLE<br>UNIT | D13-2095<br>CGLMG | D13-2119<br>CGLMG | D13-2120<br>CGLMG | D13-2048-1<br>FGLMG | D13-2057<br>FGLMG | D13-2060-2<br>FGLMG | D13-2093-2<br>FGLMG | D13-2093-3<br>FGLMG |
|----------------|-------------------|-------------------|-------------------|---------------------|-------------------|---------------------|---------------------|---------------------|
| SiO2           | 74.55             | 73.17             | 72.91             | 73.53               | 74.66             | 74.85               | 74.04               | 73.91               |
| Al2O3          | 13.33             | 14.18             | 13.52             | 14.75               | 14.02             | 14.35               | 13.70               | 14.02               |
| Fe2O3          | 1.79              | 1.67              | 1.28              | 0.91                | 1.24              | 0.98                | 0.70                | 1.16                |
| CaO            | 0.38              | 0.60              | 0.58              | 0.05                | 0.24              | 0.20                | 0.41                | 0.42                |
| MgO            | 1.24              | 1.10              | 1.04              | 0.55                | 0.75              | 0.55                | 0.87                | 0.97                |
| Na2O           | 3.43              | 3.29              | 3.79              | 2.37                | 3.12              | 3.97                | 3.05                | 4.00                |
| K2O            | 4.78              | 5.00              | 4.62              | 7.84                | 5.27              | 4.15                | 5.80                | 4.36                |
| TiO2           | 0.20              | 0.18              | 0.12              | 0.05                | 0.11              | 0.04                | 0.04                | 0.08                |
| P2O5           | 0.11              | 0.14              | 0.09              | 0.19                | 0.14              | 0.20                | 0.14                | 0.17                |
| MNO            | 0.06              | 0.06              | 0.04              | 0.19                | 0.05              | 0.13                | 0.05                | 0.06                |
| H2O            | 0.40              | 0.30              | 0.60              | 0.20                | 0.60              | 0.30                | 0.50                | 0.80                |
| Q              | 33.98             | 32.55             | 31.25             | 28.71               | 35.23             | 35.23               | 32.69               | 32.35               |
| OR             | 28.31             | 29.76             | 27.89             | 46.08               | 31.30             | 24.68               | 34.72               | 26.01               |
| AB             | 29.06             | 28.01             | 32.72             | 19.93               | 26.50             | 33.77               | 26.12               | 34.13               |
| AN             | 1.17              | 2.07              | 2.34              | 0.00                | 0.28              | 0.00                | 1.13                | 0.98                |
| C              | 2.08              | 2.61              | 1.47              | 2.34                | 3.09              | 3.34                | 2.01                | 2.38                |
| EN             | 3.09              | 2.76              | 2.64              | 1.36                | 1.88              | 1.38                | 2.19                | 2.44                |
| IL             | 0.13              | 0.13              | 0.09              | 0.09                | 0.11              | 0.08                | 0.08                | 0.13                |
| HM             | 1.79              | 1.68              | 1.31              | 0.58                | 1.24              | 0.75                | 0.68                | 1.17                |
| RU             | 0.13              | 0.11              | 0.08              | 0.00                | 0.05              | 0.00                | 0.00                | 0.01                |
| AP             | 0.26              | 0.33              | 0.21              | 0.44                | 0.33              | 0.47                | 0.33                | 0.40                |
| A/CNK          | 1.16              | 1.19              | 1.10              | 1.18                | 1.24              | 1.26                | 1.14                | 1.16                |
| TTDI           | 91.35             | 90.31             | 91.87             | 94.71               | 93.03             | 93.68               | 93.53               | 92.49               |
| Col. Ind       | 5.01              | 4.57              | 4.04              | 2.51                | 3.23              | 2.51                | 2.99                | 3.74                |
| Ba             | 384               | 188               | 113               | 144                 | 130               | 6                   | 107                 | 56                  |
| Rb             | 164               | 166               | 192               | 261                 | 186               | 235                 | 169                 | 213                 |
| Sr             | 70                | 46                | 33                | 21                  | 29                | 2                   | 25                  | 17                  |
| Zr             | 74                | 68                | 53                | 27                  | 47                | 25                  | 44                  | 41                  |
| Nb             | 7                 | 8                 | 6                 | 3                   | 6                 | 7                   | 4                   | 8                   |
| V              | 11                | 11                | 8                 | 3                   | 4                 | 0                   | 2                   | 3                   |
| Y              | 16                | 19                | 21                | 21                  | 17                | 12                  | 18                  | 14                  |
| Ga             | 20                | 17                | 19                | 17                  | 17                | 20                  | 20                  | 20                  |
| Cu             | 0                 | 0                 | 0                 | 0                   | 2                 | 0                   | 9                   | 6                   |
| Zn             | 40                | 28                | 19                | 32                  | 45                | 24                  | 26                  | 32                  |
| Hf             | 2                 | 2                 | 2                 | 1                   | 1                 | 1                   | 2                   | 2                   |
| Ta             | 0.8               | 1.4               | 1.0               | 0.8                 | 1.2               | 1.2                 | 0.0                 | 1.0                 |
| Sc             | 3.4               | 3.9               | 3.2               | 4.8                 | 2.3               | 4.4                 | 2.1                 | 3.1                 |
| La             | 11                | 11                | 8                 | 4                   | 5                 | 2                   | 5                   | 5                   |
| Th             | 5.3               | 5.6               | 5.1               | 2.1                 | 4.3               | 2.2                 | 3.1                 | 3.1                 |
| U              | 2.5               | 2.5               | 4.6               | 3.5                 | 3.7               | 10.0                | 2.8                 | 4.4                 |
| Li             | 37                | 31                | 33                | 8                   | 30                | 26                  | 13                  | 37                  |
| F              | 310               | 330               | 290               | 78                  | 135               | 105                 | 75                  | 200                 |
| As             | 0.6               | 0.5               | 0.8               | 0.9                 | 3.4               | 0.6                 | 0.0                 | 0.9                 |
| Sn             | 9                 | 6                 | 10                | 6                   | 9                 | 12                  | 7                   | 13                  |
| W              | 2                 | 1                 | 2                 | 2                   | 2                 | 1                   | 1                   | 1                   |

## BIP cont.

| SAMPLE<br>UNIT | D13-2122<br>FGLMG | D13-2124-2<br>FGLMG | D13-2125-2<br>FGLMG | D13-2127<br>FGLMG | D13-2124<br>CUMUL |
|----------------|-------------------|---------------------|---------------------|-------------------|-------------------|
| SiO2           | 74.93             | 73.84               | 72.72               | 76.37             | 63.37             |
| Al2O3          | 13.71             | 13.62               | 13.59               | 13.98             | 20.87             |
| Fe2O3          | 1.30              | 1.57                | 0.90                | 1.02              | 1.58              |
| CaO            | 0.43              | 0.40                | 0.25                | 0.27              | 3.38              |
| MgO            | 0.99              | 0.98                | 0.87                | 0.91              | 1.18              |
| Na2O           | 3.88              | 3.51                | 3.39                | 3.67              | 5.64              |
| K2O            | 4.31              | 4.60                | 5.11                | 4.75              | 2.48              |
| TiO2           | 0.05              | 0.14                | 0.05                | 0.07              | 0.18              |
| P2O5           | 0.12              | 0.13                | 0.17                | 0.09              | 0.17              |
| MnO            | 0.07              | 0.07                | 0.04                | 0.08              | 0.07              |
| H2O            | 0.40              | 0.40                | 0.90                | 0.30              | 1.10              |
| Q              | 33.86             | 34.24               | 33.03               | 34.72             | 12.68             |
| OR             | 25.55             | 27.52               | 31.13               | 27.76             | 14.83             |
| AB             | 32.90             | 30.04               | 29.54               | 30.68             | 48.24             |
| AN             | 1.35              | 1.15                | 0.13                | 0.74              | 15.83             |
| C              | 2.17              | 2.48                | 2.50                | 2.49              | 3.20              |
| EN             | 2.47              | 2.47                | 2.23                | 2.24              | 2.97              |
| IL             | 0.10              | 0.15                | 0.09                | 0.13              | 0.15              |
| HM             | 1.24              | 1.59                | 0.93                | 0.97              | 1.60              |
| RU             | 0.00              | 0.06                | 0.01                | 0.00              | 0.10              |
| AP             | 0.28              | 0.31                | 0.41                | 0.21              | 0.40              |
| A/CNK          | 1.16              | 1.19                | 1.18                | 1.20              | 1.15              |
| TTDI           | 92.31             | 91.80               | 93.71               | 93.16             | 75.75             |
| Col ind.       | 3.89              | 4.21                | 3.25                | 3.40              | 4.72              |
| Ba             | 233               | 137                 | 43                  | 58                | 216               |
| Rb             | 148               | 205                 | 136                 | 114               | 135               |
| Sr             | 37                | 29                  | 11                  | 14                | 294               |
| Zr             | 41                | 61                  | 26                  | 35                | 101               |
| Nb             | 5                 | 7                   | 3                   | 5                 | 10                |
| V              | 3                 | 5                   | 0                   | 4                 | 15                |
| Y              | 14                | 22                  | 11                  | 14                | 15                |
| Ga             | 20                | 19                  | 19                  | 15                | 30                |
| Cu             | 16                | 0                   | 0                   | 0                 | 0                 |
| Zn             | 39                | 31                  | 23                  | 20                | 42                |
| Hf             | 2                 | 2                   | 1                   | 1                 | 3                 |
| Ta             | 0.5               | 1.4                 | 0.5                 | 0.5               | 1.8               |
| Sc             | 2.1               | 3.4                 | 0.9                 | 1.5               | 3.7               |
| La             | 5                 | 9                   | 3                   | 6                 | 19                |
| Th             | 2.0               | 4.9                 | 0.9                 | 2.9               | 4.4               |
| U              | 3.1               | 4.1                 | 2.7                 | 1.8               | 1.4               |
| Li             | 28                | 45                  | 20                  | 25                | 41                |
| F              | 75                | 270                 | 65                  | 75                | 400               |
| As             | 1.4               | 1.5                 | 0.9                 | 1.6               | 1.0               |
| Sn             | 5                 | 12                  | 7                   | 6                 | 10                |
| W              | 3                 | 1                   | 1                   | 1                 | 5                 |



# DAVIS LAKE PLUTON (DLP)

| SAMPLE UNIT                    | A03-3029 | A03-3030 | A04-1206 | A04-1214 | A04-1216 | A04-1217 | A04-1218 | A03-2345-G |
|--------------------------------|----------|----------|----------|----------|----------|----------|----------|------------|
|                                | BGD      | BGD      | MBMG     | MBMG     | MBMG     | MBMG     | MBMG     | CGLMG      |
| Major Elements (wt %)          |          |          |          |          |          |          |          |            |
| SiO <sub>2</sub>               | 67.74    | 67.99    | 72.57    | 72.18    | 73.97    | 74.64    | 74.70    | 72.58      |
| Al <sub>2</sub> O <sub>3</sub> | 15.40    | 15.03    | 13.50    | 13.68    | 12.97    | 12.74    | 12.97    | 14.44      |
| Fe <sub>2</sub> O <sub>3</sub> | 4.62     | 4.28     | 2.54     | 2.48     | 1.90     | 1.94     | 1.74     | 2.03       |
| CaO                            | 1.65     | 1.52     | 1.26     | 0.68     | 0.36     | 0.29     | 0.41     | 1.07       |
| MgO                            | 1.92     | 1.74     | 1.25     | 1.16     | 1.05     | 0.90     | 0.77     | 0.96       |
| Na <sub>2</sub> O              | 3.00     | 3.63     | 3.59     | 3.62     | 3.63     | 3.38     | 3.50     | 3.31       |
| K <sub>2</sub> O               | 3.90     | 3.91     | 3.99     | 4.64     | 4.57     | 4.56     | 4.58     | 4.57       |
| TiO <sub>2</sub>               | 0.74     | 0.67     | 0.33     | 0.26     | 0.12     | 0.12     | 0.12     | 0.24       |
| P <sub>2</sub> O <sub>5</sub>  | 0.23     | 0.22     | 0.13     | 0.17     | 0.10     | 0.10     | 0.10     | 0.20       |
| MnO                            | 0.10     | 0.09     | 0.07     | 0.07     | 0.05     | 0.04     | 0.06     | 0.04       |
| H <sub>2</sub> O               | 0.60     | 0.90     | 0.60     | 1.10     | 0.70     | 0.70     | 0.80     | 0.60       |
| Normative Mineralogy           |          |          |          |          |          |          |          |            |
| Q                              | 29.81    | 26.92    | 32.46    | 30.97    | 33.73    | 36.30    | 35.42    | 32.84      |
| OR                             | 23.23    | 23.34    | 23.78    | 27.74    | 27.38    | 27.32    | 27.38    | 27.18      |
| AB                             | 25.56    | 31.00    | 30.61    | 30.96    | 31.11    | 28.97    | 29.93    | 28.16      |
| AN                             | 6.73     | 6.16     | 5.44     | 2.28     | 1.15     | 0.79     | 1.39     | 4.02       |
| C                              | 3.82     | 2.61     | 1.30     | 1.89     | 1.65     | 1.98     | 1.76     | 2.59       |
| EN                             | 4.82     | 4.37     | 3.14     | 2.92     | 2.65     | 2.27     | 1.94     | 2.40       |
| IL                             | 0.22     | 0.19     | 0.15     | 0.15     | 0.11     | 0.09     | 0.13     | 0.09       |
| HM                             | 4.65     | 4.32     | 2.56     | 2.51     | 1.92     | 1.97     | 1.76     | 2.04       |
| HY                             | 4.82     | 4.37     | 3.14     | 2.92     | 2.65     | 2.27     | 1.94     | 2.40       |
| RU                             | 0.63     | 0.57     | 0.25     | 0.18     | 0.06     | 0.06     | 0.05     | 0.20       |
| AP                             | 0.54     | 0.52     | 0.30     | 0.40     | 0.23     | 0.24     | 0.23     | 0.47       |
| A/CNK                          | 1.27     | 1.16     | 1.08     | 1.12     | 1.12     | 1.16     | 1.13     | 1.17       |
| TTDI                           | 78.60    | 81.26    | 86.85    | 89.67    | 92.22    | 92.59    | 92.73    | 88.19      |
| Col. Ind                       | 9.68     | 8.89     | 5.85     | 5.58     | 4.68     | 4.32     | 3.83     | 4.53       |
| Trace Elements (ppm*)          |          |          |          |          |          |          |          |            |
| Ba                             | 601      | 557      | 210      | 318      | 68       | 97       | 61       | 262        |
| Rb                             | 159      | 174      | 441      | 431      | 515      | 528      | 558      | 172        |
| Sr                             | 151      | 134      | 60       | 58       | 19       | 17       | 9        | 72         |
| Zr                             | 187      | 189      | 127      | 115      | 75       | 76       | 83       | 112        |
| Nb                             | 11       | 11       | 15       | 14       | 14       | 14       | 14       | 7          |
| V                              | 63       | 47       | 22       | 26       | 7        | 7        | 0        | 10         |
| Y                              | 30       | 32       | 62       | 54       | 58       | 61       | 60       | 27         |
| Ga                             | 17       | 19       | 18       | 20       | 20       | 21       | 20       | 17         |
| Cu                             | 0        | 20       | 8        | 30       | 7        | 10       | 10       | 0          |
| Zn                             | 65       | 69       | 42       | 57       | 35       | 33       | 33       | 40         |
| Hf                             | 5        | 5        | 3        | 2        | 2        | 3        | 2        | 4          |
| Ta                             | 1.2      | 1.1      | 3.1      | 2.7      | 4.1      | 4.0      | 4.2      | 0.9        |
| Sc                             | 9.5      | 8.9      | 4.5      | 4.8      | 3.2      | 3.7      | 3.5      | 2.8        |
| La                             | 27       | 28       | 22       | 19       | 13       | 15       | 13       | 18         |
| Th                             | 12.0     | 12.0     | 18.0     | 18.0     | 18.0     | 18.0     | 18.0     | 10.0       |
| U                              | 3.8      | 3.0      | 15.0     | 14.0     | 24.8     | 23.7     | 23.7     | 6.0        |
| Li                             | 69       | 69       | 171      | 142      | 107      | 122      | 136      | 42         |
| F                              | 591      | 608      | 2972     | 3140     | 2356     | 1908     | 3056     | 535        |
| As                             | 1.5      | 1.4      | 4.0      | 1.1      | 0.9      | 3.7      | 0.0      | 1.7        |
| Sn                             | 3        | 8        | 9        | 22       | 15       | 25       | 25       | 6          |
| W                              | 0        | 0        | 102      | 5        | 8        | 6        | 7        | 0          |

## DLP cont.

| SAMPLE<br>UNIT | A03-2350<br>CGLMG | A03-3000<br>CGLMG | A03-3007<br>CGLMG | A03-3009<br>CGLMG | A03-3012<br>CGLMG | A03-3024<br>CGLMG | A03-3024-A<br>CGLMG | A04-1050<br>CGLMG |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------------------|-------------------|
| SIO2           | 72.26             | 72.25             | 74.07             | 73.29             | 73.62             | 73.53             | 72.82               | 75.97             |
| AL2O3          | 15.03             | 15.09             | 14.03             | 14.00             | 13.78             | 13.71             | 14.01               | 13.30             |
| FE2O3          | 2.31              | 1.88              | 1.62              | 1.90              | 1.56              | 1.90              | 1.85                | 1.44              |
| CAO            | 1.11              | 0.59              | 0.71              | 0.70              | 0.41              | 0.50              | 0.43                | 0.28              |
| MGO            | 1.04              | 0.98              | 0.89              | 1.01              | 0.92              | 0.96              | 0.85                | 0.76              |
| NA2O           | 3.35              | 3.39              | 3.20              | 3.05              | 3.23              | 3.54              | 3.68                | 3.32              |
| K2O            | 4.57              | 5.21              | 4.48              | 4.99              | 4.96              | 4.44              | 4.61                | 4.16              |
| TIO2           | 0.30              | 0.19              | 0.20              | 0.21              | 0.12              | 0.17              | 0.16                | 0.11              |
| P2O5           | 0.24              | 0.21              | 0.20              | 0.22              | 0.21              | 0.27              | 0.27                | 0.33              |
| MNO            | 0.05              | 0.05              | 0.04              | 0.04              | 0.03              | 0.04              | 0.04                | 0.04              |
| H2O            | 0.40              | 0.40              | 0.60              | 0.70              | 0.50              | 0.60              | 0.80                | 0.40              |
| Q              | 31.93             | 30.49             | 36.21             | 34.25             | 34.58             | 34.52             | 32.75               | 39.64             |
| OR             | 26.96             | 30.87             | 26.65             | 29.69             | 29.68             | 26.51             | 27.62               | 24.64             |
| AB             | 28.27             | 28.73             | 27.23             | 25.96             | 27.65             | 30.24             | 31.54               | 28.13             |
| AN             | 3.93              | 1.55              | 2.23              | 2.04              | 0.67              | 0.72              | 0.37                | 0.00              |
| C              | 3.12              | 3.31              | 3.12              | 2.85              | 2.88              | 2.84              | 2.86                | 3.34              |
| EN             | 2.58              | 2.44              | 2.23              | 2.53              | 2.32              | 2.41              | 2.14                | 1.90              |
| IL             | 0.11              | 0.11              | 0.09              | 0.09              | 0.06              | 0.09              | 0.09                | 0.09              |
| HM             | 2.30              | 1.88              | 1.63              | 1.91              | 1.58              | 1.92              | 1.87                | 1.44              |
| HY             | 2.58              | 2.44              | 2.23              | 2.53              | 2.32              | 2.41              | 2.14                | 1.90              |
| RU             | 0.24              | 0.13              | 0.16              | 0.17              | 0.09              | 0.13              | 0.12                | 0.07              |
| AP             | 0.56              | 0.49              | 0.47              | 0.51              | 0.49              | 0.63              | 0.63                | 0.77              |
| A/CNK          | 1.20              | 1.23              | 1.23              | 1.20              | 1.21              | 1.19              | 1.18                | 1.27              |
| TTDI           | 87.16             | 90.08             | 90.09             | 89.90             | 91.91             | 91.26             | 91.91               | 92.41             |
| Col. Ind.      | 4.99              | 4.43              | 3.94              | 4.53              | 3.96              | 4.42              | 4.10                | 3.42              |
| Ba             | 409               | 313               | 237               | 275               | 122               | 134               | 168                 | 25                |
| Rb             | 208               | 321               | 213               | 240               | 346               | 388               | 385                 | 579               |
| Sr             | 82                | 52                | 54                | 54                | 22                | 24                | 28                  | 6                 |
| Zr             | 134               | 102               | 78                | 106               | 67                | 86                | 90                  | 47                |
| Nb             | 10                | 13                | 8                 | 9                 | 12                | 15                | 17                  | 19                |
| V              | 17                | 7                 | 6                 | 10                | 0                 | 7                 | 6                   | 0                 |
| Y              | 26                | 29                | 19                | 29                | 31                | 37                | 35                  | 40                |
| Ga             | 18                | 19                | 16                | 17                | 18                | 21                | 21                  | 21                |
| Cu             | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 5                   | 0                 |
| Zn             | 45                | 56                | 33                | 40                | 38                | 55                | 53                  | 53                |
| Hf             | 4                 | 3                 | 2                 | 3                 | 3                 | 2                 | 2                   | 0                 |
| Ta             | 1.5               | 2.2               | 1.4               | 1.8               | 2.2               | 2.6               | 2.8                 | 4.9               |
| Sc             | 3.7               | 2.7               | 2.1               | 2.7               | 1.7               | 2.3               | 2.4                 | 2.4               |
| La             | 22                | 18                | 14                | 17                | 10                | 12                | 12                  | 5                 |
| Th             | 12.0              | 12.0              | 9.5               | 12.0              | 10.0              | 12.0              | 12.0                | 7.5               |
| U              | 2.5               | 8.5               | 16.0              | 11.0              | 13.0              | 13.0              | 12.0                | 16.0              |
| Li             | 71                | 81                | 65                | 70                | 88                | 137               | 129                 | 269               |
| F              | 543               | 410               | 392               | 565               | 659               | 1361              | 930                 | 2400              |
| As             | 1.3               | 1.8               | 1.8               | 2.0               | 1.0               | 1.3               | 2.2                 | 2.3               |
| Sn             | 8                 | 15                | 7                 | 8                 | 10                | 15                | 12                  | 26                |
| W              | 0                 | 1                 | 0                 | 1                 | 2                 | 3                 | 3                   | 8                 |

## DLP cont.

| SAMPLE<br>UNIT | A04-1052<br>CGLMG | A04-1053<br>CGLMG | A04-1200<br>CGLMG | A04-1204<br>CGLMG | A04-1205<br>CGLMG | A04-1207<br>CGLMG | A04-1208<br>CGLMG | A04-1209<br>CGLMG |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| SiO2           | 74.37             | 73.72             | 74.33             | 74.85             | 71.03             | 75.99             | 73.21             | 75.68             |
| Al2O3          | 13.94             | 13.74             | 13.83             | 12.77             | 15.23             | 12.24             | 13.60             | 12.57             |
| Fe2O3          | 1.53              | 2.03              | 1.75              | 1.74              | 1.81              | 1.71              | 2.10              | 1.48              |
| CaO            | 0.43              | 0.50              | 0.12              | 0.34              | 0.18              | 0.51              | 0.75              | 0.39              |
| MgO            | 0.81              | 1.00              | 0.86              | 0.93              | 1.06              | 0.89              | 1.05              | 0.86              |
| Na2O           | 3.58              | 3.18              | 2.85              | 4.27              | 8.03              | 3.63              | 4.17              | 3.76              |
| K2O            | 4.62              | 4.66              | 4.82              | 5.05              | 0.84              | 4.50              | 4.33              | 4.51              |
| TiO2           | 0.12              | 0.22              | 0.08              | 0.12              | 0.16              | 0.14              | 0.19              | 0.10              |
| P2O5           | 0.29              | 0.25              | 0.12              | 0.08              | 0.15              | 0.07              | 0.07              | 0.07              |
| MnO            | 0.05              | 0.04              | 0.05              | 0.05              | 0.03              | 0.05              | 0.07              | 0.05              |
| H2O            | 0.60              | 0.50              | 1.20              | 0.60              | 0.60              | 0.40              | 0.40              | 0.70              |
| Q              | 34.63             | 35.75             | 38.45             | 28.81             | 19.82             | 35.51             | 29.53             | 34.80             |
| OR             | 27.40             | 27.75             | 28.84             | 29.81             | 5.04              | 26.69             | 25.73             | 26.82             |
| AB             | 30.37             | 27.08             | 24.39             | 36.06             | 68.95             | 30.80             | 35.44             | 31.98             |
| AN             | 0.24              | 0.85              | 0.00              | 0.75              | 0.00              | 2.08              | 3.28              | 1.48              |
| C              | 2.97              | 3.17              | 3.97              | 0.00              | 1.13              | 0.64              | 0.86              | 0.96              |
| EN             | 2.02              | 2.51              | 2.17              | 2.16              | 2.68              | 2.22              | 2.63              | 2.15              |
| IL             | 0.11              | 0.09              | 0.11              | 0.11              | 0.07              | 0.11              | 0.15              | 0.11              |
| HM             | 1.53              | 2.04              | 1.77              | 1.74              | 1.84              | 1.71              | 2.11              | 1.49              |
| HY             | 2.02              | 2.51              | 2.17              | 2.16              | 2.68              | 2.22              | 2.63              | 2.15              |
| RU             | 0.06              | 0.18              | 0.02              | 0.06              | 0.13              | 0.08              | 0.11              | 0.04              |
| AP             | 0.67              | 0.58              | 0.28              | 0.19              | 0.35              | 0.16              | 0.16              | 0.16              |
| A/CNK          | 1.19              | 1.23              | 1.37              | 0.97              | 1.05              | 1.04              | 1.05              | 1.07              |
| TTDI           | 92.40             | 90.58             | 91.68             | 94.68             | 93.81             | 93.00             | 90.70             | 93.60             |
| Cal Ind.       | 3.66              | 4.64              | 4.05              | 4.33              | 4.58              | 4.04              | 4.89              | 3.75              |
| Ba             | 87                | 166               | 53                | 71                | 23                | 65                | 219               | 63                |
| Rb             | 393               | 341               | 867               | 562               | 103               | 400               | 420               | 499               |
| Sr             | 24                | 32                | 6                 | 21                | 43                | 29                | 30                | 10                |
| Zr             | 45                | 90                | 56                | 72                | 132               | 92                | 101               | 74                |
| Nb             | 13                | 13                | 23                | 11                | 16                | 10                | 12                | 11                |
| V              | 0                 | 14                | 0                 | 6                 | 0                 | 5                 | 13                | 0                 |
| Y              | 29                | 32                | 68                | 70                | 26                | 64                | 66                | 62                |
| Ga             | 19                | 18                | 26                | 18                | 20                | 19                | 20                | 18                |
| Cu             | 0                 | 0                 | 0                 | 6                 | 0                 | 7                 | 5                 | 6                 |
| Zn             | 50                | 52                | 45                | 29                | 21                | 28                | 35                | 26                |
| Hf             | 0                 | 2                 | 0                 | 2                 | 4                 | 2                 | 3                 | 2                 |
| Ta             | 3.2               | 2.1               | 8.3               | 3.2               | 2.9               | 2.2               | 3.0               | 2.7               |
| Sc             | 2.7               | 2.9               | 3.4               | 3.7               | 3.0               | 3.6               | 4.4               | 3.7               |
| La             | 7                 | 14                | 6                 | 14                | 19                | 15                | 21                | 14                |
| Th             | 5.6               | 10.0              | 18.0              | 20.2              | 22.1              | 18.0              | 21.4              | 18.0              |
| U              | 6.9               | 6.2               | 27.2              | 23.0              | 7.4               | 18.0              | 13.0              | 20.0              |
| Li             | 120               | 74                | 335               | 130               | 32                | 82                | 118               | 144               |
| F              | 1401              | 701               | 3602              | 2180              | 264               | 1065              | 1599              | 1539              |
| As             | 4.1               | 1.7               | 2.7               | 0.7               | 0.0               | 1.3               | 3.6               | 12.0              |
| Sn             | 18                | 12                | 117               | 4                 | 17                | 5                 | 7                 | 12                |
| W              | 6                 | 13                | 11                | 13                | 1                 | 4                 | 4                 | 4                 |

## DLP cont.

| SAMPLE UNIT                    | A04-1212<br>CGLMG | A04-1213<br>CGLMG | A04-1215<br>CGLMG | A04-3000<br>CGLMG | A04-3005<br>CGLMG | A05-0014<br>CGLMG | A05-0039<br>CGLMG | A05-1006<br>CGLMG |
|--------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| SiO <sub>2</sub>               | 74.62             | 73.56             | 74.23             | 71.25             | 74.12             | 70.30             | 68.66             | 67.99             |
| Al <sub>2</sub> O <sub>3</sub> | 13.09             | 13.79             | 12.90             | 15.02             | 14.18             | 15.21             | 16.28             | 15.77             |
| Fe <sub>2</sub> O <sub>3</sub> | 1.85              | 1.76              | 1.82              | 2.17              | 1.50              | 2.33              | 2.67              | 3.81              |
| CaO                            | 0.35              | 0.42              | 0.33              | 1.05              | 0.40              | 1.38              | 1.85              | 2.00              |
| MgO                            | 0.85              | 1.06              | 0.90              | 1.00              | 0.81              | 1.09              | 1.15              | 1.38              |
| Na <sub>2</sub> O              | 3.12              | 2.80              | 3.75              | 3.62              | 3.22              | 3.08              | 3.31              | 3.47              |
| K <sub>2</sub> O               | 5.02              | 4.64              | 4.12              | 4.92              | 4.43              | 4.50              | 4.24              | 4.18              |
| TiO <sub>2</sub>               | 0.11              | 0.17              | 0.15              | 0.28              | 0.12              | 0.31              | 0.42              | 0.62              |
| P <sub>2</sub> O <sub>5</sub>  | 0.18              | 0.26              | 0.27              | 0.29              | 0.33              | 0.22              | 0.19              | 0.22              |
| MnO                            | 0.04              | 0.05              | 0.06              | 0.05              | 0.04              | 0.05              | 0.05              | 0.06              |
| H <sub>2</sub> O               | 0.60              | 0.70              | 0.80              | 0.50              | 0.60              | 0.70              | 0.70              | 0.30              |
| Q                              | 36.01             | 38.32             | 35.81             | 28.52             | 37.52             | 31.67             | 28.36             | 26.20             |
| OR                             | 29.92             | 27.86             | 24.73             | 29.20             | 26.42             | 27.03             | 25.38             | 24.85             |
| AB                             | 26.60             | 24.05             | 32.19             | 30.74             | 27.47             | 26.46             | 28.34             | 29.51             |
| AN                             | 0.56              | 0.39              | 0.00              | 3.32              | 0.00              | 5.49              | 8.03              | 8.52              |
| C                              | 2.33              | 4.08              | 2.30              | 2.53              | 4.12              | 3.34              | 3.37              | 2.44              |
| EN                             | 2.13              | 2.68              | 2.27              | 2.50              | 2.03              | 2.76              | 2.90              | 3.45              |
| IL                             | 0.09              | 0.11              | 0.13              | 0.11              | 0.09              | 0.11              | 0.11              | 0.13              |
| HM                             | 1.86              | 1.79              | 1.85              | 2.18              | 1.51              | 2.37              | 2.70              | 3.83              |
| HY                             | 2.13              | 2.68              | 2.27              | 2.50              | 2.03              | 2.76              | 2.90              | 3.45              |
| RU                             | 0.07              | 0.12              | 0.08              | 0.22              | 0.08              | 0.26              | 0.37              | 0.56              |
| AP                             | 0.42              | 0.61              | 0.64              | 0.68              | 0.77              | 0.52              | 0.45              | 0.51              |
| A/CNK                          | 1.17              | 1.33              | 1.15              | 1.14              | 1.31              | 1.22              | 1.22              | 1.14              |
| TTDI                           | 92.54             | 90.23             | 92.73             | 88.46             | 91.40             | 85.16             | 82.08             | 80.56             |
| Col. Ind.                      | 4.08              | 4.57              | 4.25              | 4.78              | 3.63              | 5.23              | 5.71              | 7.41              |
| Ba                             | 78                | 203               | 61                | 432               | 98                | 447               | 662               | 740               |
| Rb                             | 478               | 306               | 484               | 234               | 409               | 204               | 144               | 144               |
| Sr                             | 11                | 50                | 15                | 93                | 24                | 104               | 156               | 161               |
| Zr                             | 79                | 84                | 73                | 132               | 46                | 144               | 192               | 242               |
| Nb                             | 14                | 11                | 20                | 10                | 14                | 9                 | 11                | 12                |
| V                              | 0                 | 7                 | 5                 | 12                | 0                 | 13                | 24                | 41                |
| Y                              | 49                | 34                | 41                | 33                | 27                | 31                | 31                | 37                |
| Ga                             | 22                | 20                | 21                | 18                | 19                | 19                | 19                | 19                |
| Cu                             | 6                 | 7                 | 7                 | 0                 | 0                 | 0                 | 0                 | 0                 |
| Zn                             | 54                | 56                | 39                | 47                | 45                | 43                | 49                | 56                |
| Hf                             | 2                 | 3                 | 0                 | 4                 | 0                 | 4                 | 6                 | 7                 |
| Ta                             | 2.9               | 2.2               | 3.8               | 1.0               | 3.3               | 1.5               | 1.0               | 0.9               |
| Sc                             | 1.9               | 2.6               | 2.5               | 3.2               | 2.9               | 3.9               | 4.5               | 6.6               |
| La                             | 10                | 13                | 7                 | 22                | 6                 | 25                | 33                | 41                |
| Th                             | 14.0              | 9.1               | 11.0              | 10.0              | 5.8               | 12.0              | 14.0              | 18.0              |
| U                              | 12.0              | 6.4               | 21.2              | 4.1               | 7.1               | 2.6               | 2.4               | 2.8               |
| Li                             | 137               | 59                | 143               | 63                | 126               | 56                | 43                | 56                |
| F                              | 1561              | 506               | 1741              | 596               | 1052              | 806               | 522               | 736               |
| As                             | 2.3               | 3.1               | 0.0               | 2.2               | 1.5               | 2.1               | 1.7               | 1.8               |
| Sn                             | 13                | 4                 | 11                | 4                 | 15                | 10                | 7                 | 0                 |
| W                              | 4                 | 0                 | 6                 | 0                 | 5                 | 0                 | 0                 | 0                 |

## DLP cont.

| SAMPLE<br>UNIT | A05-1018<br>CGLMG | A05-8028<br>CGLMG | A06-2328<br>CGLMG | A06-3025<br>CGLMG | A04-1210<br>FGLMG | A04-1211<br>FGLMG | A04-1054<br>MLG | A04-1061<br>MLG |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-----------------|-----------------|
| SiO2           | 70.13             | 71.25             | 71.65             | 71.33             | 75.21             | 73.43             | 73.92           | 75.40           |
| Al2O3          | 15.72             | 15.05             | 15.03             | 14.27             | 13.36             | 14.00             | 14.73           | 13.05           |
| Fe2O3          | 2.43              | 1.95              | 2.21              | 1.88              | 1.59              | 1.82              | 1.23            | 4.07            |
| CaO            | 1.47              | 1.10              | 0.99              | 1.04              | 0.38              | 0.40              | 0.28            | 0.13            |
| MgO            | 1.09              | 0.92              | 1.07              | 1.13              | 0.78              | 0.83              | 0.65            | 0.82            |
| Na2O           | 3.13              | 3.22              | 3.34              | 4.06              | 3.28              | 3.47              | 4.22            | 0.81            |
| K2O            | 4.94              | 4.84              | 4.91              | 4.90              | 4.29              | 3.83              | 3.97            | 4.30            |
| TiO2           | 0.34              | 0.28              | 0.27              | 0.24              | 0.05              | 0.04              | 0.03            | 0.05            |
| P2O5           | 0.23              | 0.31              | 0.24              | 0.21              | 0.16              | 0.18              | 0.15            | 0.15            |
| MNO            | 0.04              | 0.04              | 0.05              | 0.04              | 0.06              | 0.09              | 0.08            | 0.10            |
| H2O            | 0.40              | 0.60              | 0.40              | 0.30              | 0.90              | 1.50              | 0.80            | 1.70            |
| Q              | 29.01             | 31.45             | 30.45             | 25.86             | 38.50             | 37.71             | 33.27           | 53.55           |
| OR             | 29.36             | 28.93             | 29.11             | 29.25             | 25.59             | 23.10             | 23.66           | 25.70           |
| AB             | 26.61             | 27.53             | 28.33             | 34.66             | 27.99             | 29.93             | 35.97           | 6.93            |
| AN             | 5.82              | 3.46              | 3.35              | 3.82              | 0.84              | 0.82              | 0.41            | 0.00            |
| C              | 3.11              | 3.29              | 3.00              | 0.90              | 3.04              | 3.92              | 3.36            | 7.13            |
| EN             | 2.73              | 2.32              | 2.67              | 2.84              | 1.96              | 2.11              | 1.63            | 2.06            |
| IL             | 0.09              | 0.09              | 0.11              | 0.09              | 0.10              | 0.08              | 0.06            | 0.10            |
| HM             | 2.44              | 1.97              | 2.22              | 1.90              | 1.57              | 1.73              | 1.12            | 3.99            |
| HY             | 2.73              | 2.32              | 2.67              | 2.84              | 1.96              | 2.11              | 1.63            | 2.06            |
| RU             | 0.30              | 0.24              | 0.21              | 0.20              | 0.00              | 0.00              | 0.00            | 0.00            |
| AP             | 0.54              | 0.73              | 0.56              | 0.49              | 0.37              | 0.43              | 0.35            | 0.35            |
| A/CNK          | 1.19              | 1.20              | 1.19              | 1.03              | 1.25              | 1.32              | 1.25            | 2.10            |
| TTDI           | 84.98             | 87.91             | 87.89             | 89.77             | 92.07             | 90.73             | 92.89           | 86.18           |
| Col. Ind.      | 5.26              | 4.37              | 4.99              | 4.82              | 3.67              | 4.10              | 2.98            | 6.33            |
| Ba             | 528               | 431               | 374               | 339               | 27                | 21                | 19              | 50              |
| Rb             | 192               | 172               | 260               | 220               | 570               | 817               | 1109            | 1227            |
| Sr             | 117               | 96                | 71                | 77                | 6                 | 5                 | 5               | 7               |
| Zr             | 172               | 132               | 113               | 111               | 39                | 29                | 19              | 36              |
| Nb             | 10                | 9                 | 12                | 6                 | 24                | 17                | 26              | 21              |
| V              | 18                | 14                | 19                | 15                | 0                 | 0                 | 0               | 0               |
| Y              | 34                | 27                | 28                | 30                | 56                | 63                | 68              | 81              |
| Ga             | 17                | 17                | 18                | 16                | 23                | 24                | 32              | 28              |
| Cu             | 0                 | 0                 | 0                 | 6                 | 6                 | 8                 | 0               | 543             |
| Zn             | 50                | 39                | 46                | 37                | 49                | 56                | 50              | 115             |
| Hf             | 5                 | 4                 | 3                 | 4                 | 0                 | 0                 | 0               | 0               |
| Ta             | 1.4               | 1.0               | 1.6               | 1.1               | 7.8               | 8.7               | 13.0            | 10.0            |
| Sc             | 3.7               | 2.8               | 3.4               | 2.8               | 2.3               | 2.6               | 2.7             | 2.7             |
| La             | 27                | 23                | 19                | 20                | 6                 | 5                 | 3               | 4               |
| Th             | 13.0              | 12.0              | 11.0              | 12.0              | 13.0              | 12.0              | 13.0            | 16.0            |
| U              | 2.4               | 4.0               | 4.4               | 2.9               | 11.0              | 25.5              | 20.3            | 29.2            |
| Li             | 56                | 65                | 100               | 82                | 120               | 354               | 371             | 368             |
| F              | 765               | 404               | 765               | 618               | 2968              | 5100              | 5340            | 3120            |
| As             | 1.9               | 2.2               | 2.1               | 2.0               | 0.0               | 0.0               | 0.7             | 1.8             |
| Sn             | 6                 | 3                 | 9                 | 4                 | 36                | 18                | 16              | 683             |
| W              | 0                 | 0                 | 1                 | 0                 | 7                 | 118               | 41              | 11              |



## DLP cont.

| SAMPLE<br>UNIT | A04-1201<br>MLG | A04-1202<br>MLG | A04-1203<br>MLG |
|----------------|-----------------|-----------------|-----------------|
| SiO2           | 74.19           | 73.72           | 74.06           |
| Al2O3          | 13.93           | 14.25           | 14.00           |
| Fe2O3          | 1.30            | 1.87            | 1.46            |
| CaO            | 0.43            | 0.30            | 0.31            |
| MgO            | 0.80            | 0.90            | 0.80            |
| Na2O           | 4.37            | 2.99            | 3.24            |
| K2O            | 4.28            | 3.79            | 4.15            |
| TiO2           | 0.06            | 0.06            | 0.06            |
| P2O5           | 0.36            | 0.19            | 0.33            |
| MnO            | 0.04            | 0.12            | 0.07            |
| H2O            | 0.70            | 1.10            | 1.10            |
| Q              | 31.24           | 41.11           | 38.66           |
| OR             | 25.37           | 22.83           | 24.89           |
| AB             | 37.05           | 25.76           | 27.80           |
| AN             | 0.00            | 0.25            | 0.00            |
| C              | 2.11            | 5.23            | 4.23            |
| EN             | 2.00            | 2.28            | 2.02            |
| IL             | 0.09            | 0.12            | 0.12            |
| HM             | 1.30            | 1.75            | 1.44            |
| HY             | 2.00            | 2.28            | 2.02            |
| RU             | 0.01            | 0.00            | 0.00            |
| AP             | 0.84            | 0.45            | 0.78            |
| A/CNK          | 1.11            | 1.49            | 1.35            |
| TTDI           | 93.65           | 89.70           | 91.36           |
| Col. Ind.      | 3.38            | 4.37            | 3.63            |
| Ba             | 19              | 14              | 23              |
| Rb             | 717             | 958             | 719             |
| Sr             | 19              | 17              | 24              |
| Zr             | 38              | 33              | 41              |
| Nb             | 25              | 24              | 26              |
| V              | 0               | 0               | 0               |
| Y              | 50              | 70              | 53              |
| Ga             | 24              | 27              | 26              |
| Cu             | 12              | 37              | 125             |
| Zn             | 75              | 162             | 120             |
| Hf             | 0               | 0               | 0               |
| Ta             | 6.1             | 13.0            | 6.8             |
| Sc             | 1.7             | 3.5             | 1.7             |
| La             | 3               | 4               | 3               |
| Th             | 7.9             | 14.0            | 8.1             |
| U              | 30.2            | 27.7            | 30.2            |
| Li             | 221             | 309             | 376             |
| F              | 2762            | 5600            | 2676            |
| As             | 3.2             | 1.0             | 4.6             |
| Sn             | 66              | 165             | 89              |
| W              | 10              | 19              | 12              |

# EAST DALHOUSIE PLUTON (EDP)

| SAMPLE                         | A15-0055 | A15-055-212 | A15-0055-212 | A15-0055-3 | A15-0075 | A15-0075-2 | A10-3087 | A10-3087-2 |
|--------------------------------|----------|-------------|--------------|------------|----------|------------|----------|------------|
| Rock Type                      | MBMG     | MBMG        | MBMG         | MBMG       | MBMG     | MBMG       | CGLMG    | CGLMG      |
| Major Elements (wt %)          |          |             |              |            |          |            |          |            |
| SiO <sub>2</sub>               | 72.87    | 71.85       | 72.89        | 72.17      | 72.73    | 72.50      | 72.60    | 72.03      |
| Al <sub>2</sub> O <sub>3</sub> | 14.31    | 14.65       | 14.50        | 14.80      | 14.48    | 14.43      | 14.78    | 14.96      |
| Fe <sub>2</sub> O <sub>3</sub> | 1.81     | 1.73        | 1.64         | 1.71       | 1.77     | 1.97       | 1.85     | 1.93       |
| CaO                            | 0.50     | 0.54        | 0.56         | 0.56       | 0.59     | 0.60       | 0.71     | 0.70       |
| MgO                            | 1.05     | 0.92        | 0.97         | 1.04       | 0.96     | 0.93       | 0.97     | 0.99       |
| Na <sub>2</sub> O              | 3.55     | 3.70        | 3.63         | 3.09       | 3.54     | 3.45       | 3.41     | 3.72       |
| K <sub>2</sub> O               | 5.28     | 5.05        | 4.98         | 5.06       | 4.87     | 5.17       | 4.69     | 5.03       |
| TiO <sub>2</sub>               | 0.21     | 0.21        | 0.18         | 0.22       | 0.20     | 0.22       | 0.19     | 0.23       |
| P <sub>2</sub> O <sub>5</sub>  | 0.23     | 0.27        | 0.25         | 0.25       | 0.26     | 0.25       | 0.24     | 0.25       |
| MnO                            | 0.04     | 0.04        | 0.04         | 0.04       | 0.05     | 0.05       | 0.05     | 0.05       |
| H <sub>2</sub> O               | 0.29     | 0.51        | 0.74         | 0.64       | 0.72     | 0.37       | 0.35     | 0.24       |
| Normative Mineralogy           |          |             |              |            |          |            |          |            |
| Q                              | 30.05    | 29.52       | 30.87        | 33.12      | 31.70    | 30.79      | 32.68    | 28.89      |
| OR                             | 31.28    | 30.18       | 29.56        | 30.25      | 28.97    | 30.71      | 27.88    | 29.79      |
| AB                             | 30.08    | 31.63       | 30.82        | 26.42      | 30.12    | 29.32      | 29.00    | 31.51      |
| AN                             | 0.98     | 0.92        | 1.15         | 1.15       | 1.23     | 1.35       | 1.96     | 1.84       |
| C                              | 2.40     | 2.79        | 2.72         | 3.86       | 2.95     | 2.67       | 3.39     | 2.72       |
| EN                             | 2.62     | 2.32        | 2.42         | 2.62       | 2.40     | 2.33       | 2.43     | 2.47       |
| IL                             | 0.09     | 0.09        | 0.09         | 0.09       | 0.11     | 0.11       | 0.11     | 0.11       |
| HM                             | 1.81     | 1.75        | 1.65         | 1.73       | 1.78     | 1.98       | 1.86     | 1.93       |
| RU                             | 0.17     | 0.17        | 0.14         | 0.18       | 0.14     | 0.16       | 0.13     | 0.17       |
| AP                             | 0.53     | 0.63        | 0.58         | 0.59       | 0.61     | 0.58       | 0.56     | 0.58       |
| A/CNK                          | 1.15     | 1.17        | 1.17         | 1.28       | 1.19     | 1.17       | 1.23     | 1.17       |
| TTDI                           | 91.41    | 91.34       | 91.26        | 89.79      | 90.78    | 90.82      | 89.56    | 90.18      |
| Col. Ind.                      | 4.52     | 4.15        | 4.16         | 4.43       | 4.29     | 4.41       | 4.39     | 4.51       |
| Trace Elements (ppm*)          |          |             |              |            |          |            |          |            |
| Ba                             | 336      | 288         | 322          | 296        | 282      | 315        | 185      | 285        |
| Rb                             | 294      | 290         | 297          | 277        | 309      | 315        | 287      | 272        |
| Sr                             | 51       | 53          | 58           | 55         | 51       | 55         | 45       | 54         |
| Zr                             | 103      | 94          | 96           | 99         | 98       | 104        | 87       | 83         |
| Nb                             | 14       | 13          | 14           | 13         | 14       | 15         | 10       | 10         |
| V                              | 5        | 7           | 7            | 7          | 6        | 5          | 5        | 11         |
| Y                              | 26       | 19          | 24           | 22         | 23       | 25         | 27       | 24         |
| Ga                             | 19       | 20          | 19           | 18         | 17       | 23         | 19       | 19         |
| Cu                             | 0        | 0           | 0            | 6          | 0        | 0          | 0        | 0          |
| Zn                             | 48       | 53          | 48           | 50         | 53       | 54         | 52       | 50         |
| Hf                             | 3        | 4           | 3            | 3          | 3        | 3          | 3        | 2          |
| Ta                             | 1.9      | 2.0         | 2.0          | 1.7        | 2.4      | 2.4        | 1.8      | 2.0        |
| Sc                             | 2.9      | 2.8         | 2.9          | 2.8        | 3.2      | 3.2        | 3.2      | 2.8        |
| La                             | 23       | 20          | 18           | 19         | 20       | 20         | 13       | 19         |
| Th                             | 15.0     | 15.0        | 12.0         | 15.0       | 12.0     | 14.0       | 7.8      | 17.0       |
| U                              | 4.1      | 3.5         | 4.0          | 3.1        | 4.8      | 8.5        | 5.1      | 4.1        |
| Li                             | 85       | 93          | 94           | 79         | 99       | 126        | 85       | 58         |
| F                              | 1075     | 1035        | 985          | 995        | 1090     | 1090       | 1050     | 1020       |
| As                             | 4.8      | 4.2         | 7.3          | 3.5        | 1.8      | 2.9        | 1.7      | 2.4        |
| Sn                             | 13       | 13          | 8            | 5          | 16       | 13         | 14       | 10         |
| W                              | 2        | 2           | 4            | 2          | 4        | 4          | 0        | 0          |

## EDP cont.

| SAMPLE<br>Rock Type            | A10-3100<br>CGLMG | A10-3100-1<br>CGLMG | A10-3120G<br>CGLMG | A15-0002<br>CGLMG | A15-0003<br>CGLMG | A15-0054<br>CGLMG | A15-0060<br>CGLMG | A15-0060-2<br>CGLMG |
|--------------------------------|-------------------|---------------------|--------------------|-------------------|-------------------|-------------------|-------------------|---------------------|
| SiO <sub>2</sub>               | 73.01             | 72.74               | 71.90              | 72.95             | 71.49             | 74.18             | 74.04             | 74.13               |
| Al <sub>2</sub> O <sub>3</sub> | 14.40             | 14.68               | 14.82              | 14.55             | 15.12             | 14.03             | 14.30             | 13.98               |
| Fe <sub>2</sub> O <sub>3</sub> | 1.90              | 1.97                | 1.70               | 1.67              | 2.03              | 1.40              | 1.44              | 1.63                |
| CaO                            | 0.60              | 0.59                | 0.55               | 0.51              | 0.46              | 0.27              | 0.31              | 0.38                |
| MgO                            | 0.88              | 0.86                | 1.02               | 0.91              | 0.90              | 0.78              | 0.80              | 0.79                |
| Na <sub>2</sub> O              | 3.18              | 3.08                | 3.34               | 3.31              | 3.15              | 3.58              | 3.12              | 3.30                |
| K <sub>2</sub> O               | 4.78              | 4.91                | 4.90               | 4.96              | 5.41              | 4.77              | 4.70              | 4.79                |
| TiO <sub>2</sub>               | 0.20              | 0.21                | 0.23               | 0.17              | 0.24              | 0.11              | 0.13              | 0.15                |
| P <sub>2</sub> O <sub>5</sub>  | 0.22              | 0.22                | 0.29               | 0.26              | 0.28              | 0.26              | 0.30              | 0.25                |
| MnO                            | 0.05              | 0.05                | 0.04               | 0.04              | 0.04              | 0.03              | 0.04              | 0.04                |
| H <sub>2</sub> O               | 0.25              | 0.35                | 0.76               | 0.80              | 0.70              | 0.40              | 0.83              | 0.72                |
| Q                              | 34.49             | 34.33               | 32.21              | 33.20             | 31.18             | 34.10             | 36.97             | 35.50               |
| OR                             | 28.50             | 29.24               | 29.34              | 29.54             | 32.28             | 28.36             | 28.01             | 28.49               |
| AB                             | 27.12             | 26.24               | 28.60              | 28.19             | 26.89             | 30.45             | 26.59             | 28.08               |
| AN                             | 1.55              | 1.50                | 0.84               | 0.83              | 0.45              | 0.00              | 0.00              | 0.25                |
| C                              | 3.45              | 3.78                | 3.76               | 3.45              | 3.95              | 2.99              | 4.11              | 3.29                |
| EN                             | 2.21              | 2.16                | 2.57               | 2.28              | 2.26              | 1.95              | 2.01              | 1.98                |
| IL                             | 0.11              | 0.11                | 0.09               | 0.09              | 0.09              | 0.06              | 0.09              | 0.09                |
| HM                             | 1.91              | 1.98                | 1.72               | 1.68              | 2.05              | 1.41              | 1.45              | 1.64                |
| RU                             | 0.14              | 0.15                | 0.19               | 0.13              | 0.20              | 0.08              | 0.09              | 0.11                |
| AP                             | 0.51              | 0.51                | 0.68               | 0.61              | 0.66              | 0.61              | 0.70              | 0.58                |
| A/CNK                          | 1.25              | 1.28                | 1.26               | 1.24              | 1.27              | 1.22              | 1.33              | 1.24                |
| TTDI                           | 90.11             | 89.81               | 90.15              | 90.93             | 90.35             | 92.90             | 91.56             | 92.07               |
| Col. Ind.                      | 4.23              | 4.25                | 4.38               | 4.05              | 4.40              | 3.42              | 3.54              | 3.70                |
| Ba                             | 239               | 252                 | 323                | 172               | 230               | 60                | 97                | 99                  |
| Rb                             | 256               | 262                 | 306                | 310               | 361               | 443               | 408               | 334                 |
| Sr                             | 44                | 45                  | 52                 | 37                | 40                | 21                | 20                | 29                  |
| Zr                             | 84                | 87                  | 91                 | 83                | 104               | 56                | 53                | 68                  |
| Nb                             | 9                 | 10                  | 13                 | 13                | 16                | 13                | 13                | 13                  |
| V                              | 8                 | 10                  | 7                  | 7                 | 6                 | 5                 | 0                 | 0                   |
| Y                              | 25                | 24                  | 21                 | 19                | 21                | 21                | 26                | 26                  |
| Ga                             | 18                | 18                  | 19                 | 26                | 26                | 23                | 19                | 20                  |
| Cu                             | 0                 | 0                   | 0                  | 0                 | 0                 | 0                 | 0                 | 0                   |
| Zn                             | 51                | 50                  | 48                 | 53                | 66                | 77                | 52                | 53                  |
| Hf                             | 3                 | 3                   | 3                  | 3                 | 3                 | 2                 | 2                 | 3                   |
| Ta                             | 1.6               | 1.6                 | 2.1                | 4.8               | 2.1               | 2.7               | 2.3               | 1.4                 |
| Sc                             | 3.1               | 3.5                 | 3.3                | 2.1               | 2.6               | 2.2               | 1.6               | 1.6                 |
| La                             | 16                | 17                  | 19                 | 16                | 21                | 7                 | 8                 | 10                  |
| Th                             | 12.0              | 13.0                | 14.0               | 12.0              | 15.0              | 6.1               | 5.2               | 7.1                 |
| U                              | 6.2               | 6.5                 | 4.6                | 4.2               | 6.6               | 2.2               | 2.0               | 3.3                 |
| Li                             | 91                | 99                  | 93                 | 138               | 164               | 209               | 135               | 116                 |
| F                              | 925               | 1000                | 1190               | 1225              | 1575              | 1650              | 1525              | 1420                |
| As                             | 1.5               | 1.6                 | 2.9                | 2.2               | 2.0               | 4.7               | 3.1               | 5.4                 |
| Sn                             | 7                 | 6                   | 17                 | 15                | 18                | 20                | 16                | 12                  |
| W                              | 0                 | 2                   | 4                  | 3                 | 3                 | 3                 | 3                 | 2                   |

## EDP cont.

| SAMPLE<br>Rock Type | A15-0062<br>CGLMG | A15-0067-2<br>CGLMG | A15-0101<br>CGLMG | A10-3001<br>FGLMG | A10-3054<br>FGLMG | A10-3056<br>FGLMG | A10-3057<br>FGLMG | A10-3057G<br>FGLMG |
|---------------------|-------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|
| SIO2                | 76.36             | 72.86               | 73.34             | 74.53             | 74.05             | 74.70             | 74.46             | 74.06              |
| AL2O3               | 12.89             | 14.52               | 13.90             | 13.93             | 14.51             | 14.45             | 14.03             | 14.30              |
| FE2O3               | 1.11              | 1.64                | 1.97              | 1.44              | 1.12              | 1.03              | 1.16              | 1.21               |
| CAO                 | 0.34              | 0.41                | 0.57              | 0.32              | 0.30              | 0.28              | 0.24              | 0.33               |
| MGO                 | 0.73              | 0.80                | 0.97              | 0.76              | 0.73              | 0.78              | 0.80              | 0.85               |
| NA2O                | 3.41              | 3.76                | 3.27              | 3.10              | 3.71              | 3.22              | 3.65              | 3.95               |
| K2O                 | 4.30              | 4.96                | 4.52              | 4.37              | 4.20              | 4.28              | 4.33              | 4.17               |
| TIO2                | 0.07              | 0.11                | 0.19              | 0.12              | 0.06              | 0.07              | 0.09              | 0.09               |
| P2O5                | 0.27              | 0.23                | 0.22              | 0.29              | 0.36              | 0.32              | 0.29              | 0.38               |
| MNO                 | 0.03              | 0.05                | 0.05              | 0.04              | 0.04              | 0.04              | 0.03              | 0.05               |
| H2O                 | 0.44              | 0.35                | 0.60              | 0.65              | 0.46              | 0.70              | 0.23              | 0.80               |
| Q                   | 39.15             | 30.77               | 35.31             | 39.03             | 35.56             | 38.68             | 35.73             | 33.99              |
| OR                  | 25.56             | 29.53               | 27.01             | 26.12             | 25.03             | 25.49             | 25.81             | 24.77              |
| AB                  | 28.99             | 32.02               | 27.95             | 26.50             | 31.62             | 27.43             | 31.12             | 33.57              |
| AN                  | 0.00              | 0.53                | 1.40              | 0.00              | 0.00              | 0.00              | 0.00              | 0.00               |
| C                   | 2.63              | 2.79                | 3.15              | 4.14              | 3.89              | 4.55              | 3.36              | 3.30               |
| EN                  | 1.83              | 2.01                | 2.44              | 1.91              | 1.83              | 1.96              | 2.01              | 2.13               |
| IL                  | 0.06              | 0.11                | 0.11              | 0.09              | 0.09              | 0.09              | 0.06              | 0.11               |
| HM                  | 1.12              | 1.65                | 1.99              | 1.46              | 1.13              | 1.04              | 1.17              | 1.22               |
| RU                  | 0.04              | 0.05                | 0.14              | 0.08              | 0.02              | 0.03              | 0.06              | 0.03               |
| AP                  | 0.63              | 0.54                | 0.52              | 0.68              | 0.84              | 0.75              | 0.68              | 0.89               |
| A/CNK               | 1.18              | 1.18                | 1.23              | 1.34              | 1.30              | 1.38              | 1.26              | 1.23               |
| TTDI                | 93.69             | 92.33               | 90.26             | 91.65             | 92.21             | 91.60             | 92.66             | 92.33              |
| Col. Ind.           | 3.01              | 3.76                | 4.54              | 3.45              | 3.05              | 3.08              | 3.24              | 3.45               |
| Ba                  | 50                | 97                  | 124               | 82                | 26                | 6                 | 41                | 23                 |
| Rb                  | 333               | 317                 | 303               | 383               | 567               | 497               | 430               | 506                |
| Sr                  | 16                | 22                  | 45                | 20                | 0                 | 3                 | 10                | 8                  |
| Zr                  | 51                | 46                  | 86                | 54                | 34                | 37                | 41                | 42                 |
| Nb                  | 11                | 9                   | 11                | 13                | 15                | 13                | 13                | 15                 |
| V                   | 6                 | 0                   | 9                 | 0                 | 0                 | 2                 | 0                 | 1                  |
| Y                   | 18                | 25                  | 26                | 22                | 27                | 18                | 26                | 19                 |
| Ga                  | 18                | 18                  | 20                | 21                | 25                | 28                | 21                | 24                 |
| Cu                  | 0                 | 0                   | 0                 | 0                 | 0                 | 0                 | 0                 | 0                  |
| Zn                  | 47                | 52                  | 52                | 48                | 51                | 46                | 47                | 65                 |
| Hf                  | 1                 | 2                   | 4                 | 2                 | 2                 | 1                 | 2                 | 1                  |
| Ta                  | 2.1               | 1.0                 | 1.8               | 2.7               | 5.1               | 13.0              | 3.3               | 3.2                |
| Sc                  | 1.2               | 1.9                 | 3.4               | 3.2               | 2.1               | 2.6               | 3.1               | 2.4                |
| La                  | 6                 | 6                   | 15                | 7                 | 0                 | 3                 | 3                 | 4                  |
| Th                  | 3.9               | 5.9                 | 8.7               | 5.6               | 2.2               | 2.5               | 3.8               | 3.5                |
| U                   | 10.0              | 3.8                 | 3.1               | 11.0              | 4.0               | 2.4               | 5.0               | 4.1                |
| Li                  | 95                | 79                  | 109               | 172               | 76                | 254               | 73                | 341                |
| F                   | 1285              | 1140                | 890               | 1000              | 1770              | 1950              | 1085              | 3200               |
| As                  | 4.4               | 0.9                 | 0.6               | 2.7               | 2.0               | 0.7               | 1.5               | 39.0               |
| Sn                  | 18                | 11                  | 8                 | 16                | 39                | 30                | 26                | 48                 |
| W                   | 2                 | 2                   | 2                 | 5                 | 8                 | 8                 | 6                 | 10                 |

## EDP cont.

| SAMPLE<br>Rock Type | A10-3060<br>FGLMG | A10-3074<br>FGLMG | A10-3082<br>FGLMG | A10-3093<br>FGLMG | A10-3059G<br>FGLMG | A10-3121-1<br>FGLMG | A10-3129-1<br>FGLMG | A11-2301-1<br>FGLMG |
|---------------------|-------------------|-------------------|-------------------|-------------------|--------------------|---------------------|---------------------|---------------------|
| SiO2                | 73.79             | 74.38             | 73.39             | 72.56             | 72.25              | 74.32               | 73.52               | 73.33               |
| Al2O3               | 14.57             | 14.36             | 14.64             | 14.70             | 14.91              | 14.10               | 14.54               | 14.52               |
| Fe2O3               | 1.01              | 1.15              | 1.57              | 1.50              | 1.55               | 1.30                | 1.34                | 1.34                |
| CaO                 | 0.25              | 0.32              | 0.46              | 0.40              | 0.35               | 0.37                | 0.47                | 0.45                |
| MgO                 | 0.65              | 0.69              | 0.92              | 1.10              | 1.01               | 0.63                | 0.78                | 0.90                |
| Na2O                | 3.45              | 3.29              | 3.48              | 3.04              | 3.70               | 3.33                | 3.78                | 3.77                |
| K2O                 | 4.29              | 4.57              | 4.51              | 4.69              | 4.87               | 4.34                | 4.36                | 4.50                |
| TiO2                | 0.03              | 0.07              | 0.16              | 0.19              | 0.19               | 0.12                | 0.12                | 0.12                |
| P2O5                | 0.44              | 0.29              | 0.31              | 0.24              | 0.27               | 0.34                | 0.30                | 0.32                |
| MNO                 | 0.02              | 0.03              | 0.04              | 0.05              | 0.05               | 0.04                | 0.06                | 0.05                |
| H2O                 | 0.63              | 0.47              | 0.34              | 0.73              | 0.80               | 0.74                | 0.52                | 0.60                |
| Q                   | 36.75             | 37.00             | 34.57             | 35.64             | 30.83              | 37.77               | 33.75               | 32.99               |
| OR                  | 25.68             | 27.25             | 26.82             | 28.17             | 29.05              | 25.94               | 25.98               | 26.81               |
| AB                  | 29.53             | 28.06             | 29.60             | 26.12             | 31.57              | 28.47               | 32.22               | 32.12               |
| AN                  | 0.00              | 0.00              | 0.25              | 0.42              | 0.00               | 0.00                | 0.37                | 0.14                |
| C                   | 4.30              | 4.03              | 3.96              | 4.54              | 3.58               | 3.96                | 3.49                | 3.42                |
| EN                  | 1.64              | 1.73              | 2.30              | 2.78              | 2.54               | 1.59                | 1.96                | 2.26                |
| IL                  | 0.04              | 0.06              | 0.09              | 0.11              | 0.11               | 0.09                | 0.13                | 0.11                |
| HM                  | 1.02              | 1.16              | 1.58              | 1.52              | 1.56               | 1.31                | 1.35                | 1.35                |
| RU                  | 0.01              | 0.04              | 0.12              | 0.14              | 0.13               | 0.08                | 0.05                | 0.06                |
| AP                  | 1.03              | 0.68              | 0.72              | 0.57              | 0.63               | 0.80                | 0.70                | 0.75                |
| A/CNK               | 1.35              | 1.31              | 1.28              | 1.36              | 1.24               | 1.30                | 1.23                | 1.22                |
| TTDI                | 91.96             | 92.30             | 90.98             | 89.93             | 91.45              | 92.18               | 91.95               | 91.92               |
| Col. Ind            | 2.70              | 2.96              | 3.97              | 4.41              | 4.21               | 2.99                | 3.44                | 3.71                |
| Ba                  | 18                | 12                | 174               | 233               | 249                | 124                 | 174                 | 275                 |
| Rb                  | 668               | 304               | 353               | 247               | 273                | 393                 | 226                 | 253                 |
| Sr                  | 11                | 9                 | 37                | 50                | 46                 | 15                  | 39                  | 40                  |
| Zr                  | 14                | 39                | 67                | 79                | 75                 | 48                  | 48                  | 45                  |
| Nb                  | 23                | 12                | 11                | 11                | 11                 | 16                  | 9                   | 7                   |
| V                   | 0                 | 0                 | 0                 | 7                 | 9                  | 5                   | 0                   | 6                   |
| Y                   | 29                | 24                | 24                | 20                | 18                 | 22                  | 17                  | 19                  |
| Ga                  | 29                | 21                | 23                | 17                | 18                 | 21                  | 16                  | 15                  |
| Cu                  | 0                 | 13                | 0                 | 0                 | 0                  | 7                   | 0                   | 0                   |
| Zn                  | 56                | 29                | 52                | 44                | 46                 | 40                  | 23                  | 28                  |
| Hf                  | 0                 | 2                 | 2                 | 2                 | 2                  | 0                   | 0                   | 0                   |
| Ta                  | 3.8               | 2.0               | 2.6               | 1.4               | 1.6                | 3.2                 | 1.5                 | 2.0                 |
| Sc                  | 2.6               | 2.8               | 3.0               | 2.6               | 3.1                | 2.7                 | 2.6                 | 2.3                 |
| La                  | 0                 | 3                 | 11                | 13                | 16                 | 6                   | 6                   | 7                   |
| Th                  | 1.1               | 3.0               | 10.0              | 10.0              | 10.0               | 5.2                 | 2.6                 | 3.7                 |
| U                   | 1.9               | 7.6               | 11.0              | 3.4               | 4.5                | 7.3                 | 4.1                 | 1.7                 |
| Li                  | 70                | 47                | 161               | 75                | 89                 | 63                  | 120                 | 75                  |
| F                   | 1660              | 495               | 1125              | 490               | 600                | 1355                | 320                 | 519                 |
| As                  | 47                | 4.1               | 10.0              | 2.2               | 2.3                | 14.0                | 3.0                 | 3.3                 |
| Sn                  | 24                | 13                | 18                | 10                | 13                 | 29                  | 10                  | 14                  |
| W                   | 6                 | 2                 | 5                 | 1                 | 3                  | 7                   | 1                   | 5                   |

## EDP cont.

| SAMPLE<br>Rock Type | A11-2301-2<br>FGLMG | A15-0044-2<br>FGLMG | A15-0044-3<br>FGLMG | A15-0046<br>FGLMG | A15-0046-2<br>FGLMG | A15-0046-3<br>FGLMG | A15-0147<br>FGLMG | A15-0147-2<br>FGLMG |
|---------------------|---------------------|---------------------|---------------------|-------------------|---------------------|---------------------|-------------------|---------------------|
| SiO2                | 74.01               | 74.37               | 73.35               | 74.40             | 75.12               | 73.03               | 71.26             | 71.82               |
| Al2O3               | 14.27               | 14.40               | 14.02               | 14.15             | 14.16               | 14.11               | 14.97             | 15.03               |
| Fe2O3               | 1.46                | 1.28                | 1.33                | 1.43              | 1.45                | 1.31                | 2.13              | 1.67                |
| CaO                 | 0.41                | 0.30                | 0.28                | 0.31              | 0.31                | 0.34                | 0.95              | 0.44                |
| MgO                 | 0.91                | 0.74                | 0.81                | 0.84              | 0.85                | 0.84                | 0.97              | 1.07                |
| Na2O                | 3.36                | 3.61                | 3.25                | 3.18              | 3.14                | 3.68                | 3.32              | 3.51                |
| K2O                 | 4.56                | 4.31                | 4.44                | 4.41              | 4.64                | 4.30                | 4.11              | 5.13                |
| TiO2                | 0.14                | 0.10                | 0.08                | 0.07              | 0.10                | 0.13                | 0.28              | 0.26                |
| P2O5                | 0.27                | 0.33                | 0.29                | 0.28              | 0.27                | 0.31                | 0.27              | 0.28                |
| MnO                 | 0.05                | 0.03                | 0.04                | 0.04              | 0.05                | 0.03                | 0.06              | 0.03                |
| H2O                 | 0.80                | 0.40                | 0.80                | 0.90              | 0.60                | 0.70                | 0.80              | 0.70                |
| Q                   | 35.73               | 35.90               | 36.97               | 38.07             | 37.76               | 34.54               | 34.06             | 30.23               |
| OR                  | 27.12               | 25.59               | 26.80               | 26.30             | 27.41               | 25.91               | 24.73             | 30.58               |
| AB                  | 28.59               | 30.66               | 28.06               | 27.13             | 26.53               | 31.72               | 28.57             | 29.92               |
| AN                  | 0.27                | 0.00                | 0.00                | 0.00              | 0.00                | 0.00                | 3.00              | 0.35                |
| C                   | 3.73                | 3.81                | 3.94                | 4.18              | 3.96                | 3.46                | 4.04              | 3.60                |
| EN                  | 2.28                | 1.85                | 2.06                | 2.11              | 2.11                | 2.13                | 2.46              | 2.69                |
| IL                  | 0.11                | 0.06                | 0.09                | 0.09              | 0.11                | 0.07                | 0.13              | 0.06                |
| HM                  | 1.47                | 1.29                | 1.36                | 1.44              | 1.45                | 1.33                | 2.17              | 1.68                |
| RU                  | 0.08                | 0.07                | 0.04                | 0.03              | 0.04                | 0.10                | 0.22              | 0.23                |
| AP                  | 0.63                | 0.77                | 0.69                | 0.65              | 0.63                | 0.73                | 0.64              | 0.65                |
| A/CNK               | 1.27                | 1.29                | 1.32                | 1.34              | 1.32                | 1.25                | 1.29              | 1.24                |
| TTDI                | 91.44               | 92.16               | 91.83               | 91.51             | 91.70               | 92.18               | 87.35             | 90.74               |
| Col. Ind.           | 3.85                | 3.20                | 3.50                | 3.64              | 3.67                | 3.53                | 4.75              | 4.43                |
| Ba                  | 147                 | 32                  | 22                  | 20                | 59                  | 82                  | 505               | 399                 |
| Rb                  | 252                 | 442                 | 426                 | 411               | 463                 | 406                 | 194               | 213                 |
| Sr                  | 33                  | 8                   | 8                   | 6                 | 16                  | 28                  | 121               | 60                  |
| Zr                  | 52                  | 49                  | 47                  | 48                | 61                  | 54                  | 135               | 89                  |
| Nb                  | 8                   | 14                  | 14                  | 11                | 12                  | 13                  | 14                | 11                  |
| V                   | 0                   | 3                   | 1                   | 1                 | 4                   | 5                   | 14                | 11                  |
| Y                   | 21                  | 18                  | 20                  | 20                | 20                  | 19                  | 18                | 18                  |
| Ga                  | 17                  | 23                  | 24                  | 25                | 20                  | 24                  | 19                | 20                  |
| Cu                  | 0                   | 0                   | 0                   | 1                 | 0                   | 0                   | 2                 | 0                   |
| Zn                  | 28                  | 45                  | 57                  | 66                | 53                  | 54                  | 66                | 54                  |
| Hf                  | 2                   | 1                   | 1                   | 1                 | 1                   | 1                   | 4                 | 3                   |
| Ta                  | 2.0                 | 5.5                 | 2.8                 | 2.7               | 2.5                 | 2.8                 | 2.2               | 1.9                 |
| Sc                  | 3.2                 | 2.7                 | 2.3                 | 2.3               | 2.8                 | 2.9                 | 5.1               | 3.4                 |
| La                  | 8                   | 5                   | 5                   | 5                 | 7                   | 7                   | 28                | 17                  |
| Th                  | 4.8                 | 3.7                 | 3.7                 | 4.2               | 5.4                 | 5.1                 | 7.8               | 13.0                |
| U                   | 6.6                 | 3.8                 | 3.6                 | 3.4               | 2.3                 | 5.9                 | 6.0               | 4.0                 |
| Li                  | 73                  | 235                 | 212                 | 256               | 386                 | 213                 | 137               | 87                  |
| F                   | 369                 | 1075                | 1150                | 1450              | 1800                | 1400                | 660               | 350                 |
| As                  | 12.0                | 2.0                 | 3.3                 | 7.4               | 1.3                 | 4.3                 | 2.5               | 6.4                 |
| Sn                  | 12                  | 26                  | 26                  | 35                | 36                  | 22                  | 10                | 11                  |
| W                   | 4                   | 5                   | 8                   | 10                | 6                   | 5                   | 2                 | 1                   |



## EDP cont.

| SAMPLE<br>Rock Type | A15-0008<br>MLG | A15-0008-3<br>MLG | A15-0008-4<br>MLG | A15-0014-2<br>MLG | A15-0014-3<br>MLG | A15-0014-4<br>MLG | A15-0018<br>MLG | A15-0020<br>MLG |
|---------------------|-----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-----------------|-----------------|
| SiO2                | 72.20           | 72.56             | 72.20             | 73.30             | 73.44             | 73.95             | 74.05           | 74.21           |
| Al2O3               | 15.43           | 15.29             | 15.50             | 14.99             | 14.24             | 14.43             | 13.79           | 14.13           |
| Fe2O3               | 1.03            | 1.26              | 1.15              | 1.25              | 1.08              | 1.06              | 1.39            | 1.57            |
| CaO                 | 0.43            | 0.57              | 0.60              | 0.50              | 0.30              | 0.35              | 0.38            | 0.38            |
| MgO                 | 0.72            | 0.66              | 0.63              | 0.84              | 0.77              | 0.71              | 0.87            | 0.79            |
| Na2O                | 3.58            | 3.97              | 4.20              | 3.69              | 4.02              | 3.29              | 3.19            | 3.41            |
| K2O                 | 4.33            | 3.46              | 3.48              | 3.82              | 4.35              | 4.30              | 4.35            | 4.40            |
| TiO2                | 0.01            | 0.02              | 0.02              | 0.07              | 0.08              | 0.05              | 0.09            | 0.08            |
| P2O5                | 0.67            | 0.69              | 0.71              | 0.48              | 0.36              | 0.35              | 0.29            | 0.36            |
| MNO                 | 0.03            | 0.04              | 0.04              | 0.04              | 0.03              | 0.03              | 0.03            | 0.04            |
| H2O                 | 0.80            | 0.91              | 0.81              | 1.11              | 0.87              | 0.77              | 0.80            | 0.84            |
| Q                   | 34.10           | 35.64             | 33.88             | 36.27             | 32.62             | 37.80             | 38.13           | 36.54           |
| OR                  | 25.90           | 20.70             | 20.82             | 22.80             | 26.03             | 25.79             | 26.14           | 26.17           |
| AB                  | 30.63           | 33.98             | 35.94             | 31.50             | 34.41             | 28.22             | 27.42           | 29.01           |
| AN                  | 0.00            | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              | 0.00            | 0.00            |
| C                   | 4.90            | 5.07              | 4.88              | 4.82              | 2.95              | 4.42              | 3.89            | 3.77            |
| EN                  | 1.81            | 1.66              | 1.59              | 2.11              | 1.94              | 1.79              | 2.20            | 1.98            |
| IL                  | 0.02            | 0.04              | 0.04              | 0.09              | 0.06              | 0.07              | 0.07            | 0.09            |
| HM                  | 0.99            | 1.22              | 1.11              | 1.26              | 1.09              | 1.07              | 1.41            | 1.58            |
| RU                  | 0.00            | 0.00              | 0.00              | 0.03              | 0.05              | 0.02              | 0.06            | 0.04            |
| AP                  | 1.57            | 1.62              | 1.67              | 1.12              | 0.84              | 0.82              | 0.68            | 0.84            |
| A/CNK               | 1.38            | 1.35              | 1.32              | 1.35              | 1.20              | 1.35              | 1.30            | 1.28            |
| TTDI                | 90.63           | 90.31             | 90.65             | 90.57             | 93.06             | 91.81             | 91.69           | 91.71           |
| Col. Ind.           | 2.90            | 3.00              | 2.81              | 3.46              | 3.10              | 2.93              | 3.68            | 3.64            |
| Ba                  | 37              | 14                | 24                | 15                | 54                | 33                | 47              | 42              |
| Rb                  | 843             | 745               | 737               | 650               | 497               | 539               | 396             | 473             |
| Sr                  | 14              | 21                | 24                | 10                | 10                | 7                 | 16              | 17              |
| Zr                  | 23              | 42                | 16                | 34                | 33                | 23                | 51              | 40              |
| Nb                  | 30              | 29                | 28                | 30                | 16                | 18                | 13              | 16              |
| V                   | 1               | 0                 | 7                 | 0                 | 0                 | 0                 | 1               | 0               |
| Y                   | 22              | 34                | 36                | 34                | 27                | 25                | 19              | 27              |
| Ga                  | 33              | 34                | 32                | 31                | 24                | 24                | 23              | 20              |
| Cu                  | 0               | 0                 | 0                 | 8                 | 0                 | 0                 | 0               | 0               |
| Zn                  | 72              | 75                | 77                | 51                | 36                | 27                | 39              | 63              |
| Hf                  | 4               | 4                 | 0                 | 0                 | 1                 | 0                 | 1               | 1               |
| Ta                  | 0.9             | 5.0               | 4.1               | 5.9               | 3.0               | 4.2               | 1.1             | 3.3             |
| Sc                  | 5.8             | 1.7               | 1.4               | 5.4               | 2.1               | 2.2               | 1.9             | 1.6             |
| La                  | 25              | 0                 | 0                 | 0                 | 6                 | 2                 | 5               | 5               |
| Th                  | 12.0            | 1.7               | 1.1               | 2.1               | 4.4               | 1.9               | 5.0             | 3.6             |
| U                   | 2.6             | 3.8               | 2.6               | 2.5               | 2.2               | 1.7               | 4.0             | 2.2             |
| Li                  | 205             | 205               | 205               | 173               | 134               | 97                | 122             | 153             |
| F                   | 2300            | 2645              | 2705              | 2100              | 1500              | 1640              | 1450            | 1860            |
| As                  | 2.7             | 3.8               | 4.2               | 2.7               | 2.0               | 3.2               | 3.7             | 3.1             |
| Sn                  | 28              | 26                | 27                | 29                | 25                | 23                | 21              | 20              |
| W                   | 2               | 8                 | 8                 | 8                 | 5                 | 6                 | 4               | 4               |

## EDP cont.

| SAMPLE<br>Rock Type | A15-0020-2<br>MLG | A15-0027<br>MLG | A15-0041<br>MLG | A15-0067<br>MLG | A15-0068<br>MLG | A15-0068-2<br>MLG | A15-0068-3<br>MLG | A15-0075-22<br>MLG |
|---------------------|-------------------|-----------------|-----------------|-----------------|-----------------|-------------------|-------------------|--------------------|
| SiO2                | 72.97             | 74.99           | 73.55           | 74.31           | 73.93           | 75.17             | 72.78             | 73.68              |
| Al2O3               | 15.01             | 14.18           | 14.66           | 14.05           | 14.66           | 14.16             | 15.04             | 14.33              |
| Fe2O3               | 1.18              | 1.04            | 1.18            | 1.50            | 1.10            | 0.97              | 0.91              | 1.36               |
| CaO                 | 0.73              | 0.37            | 0.45            | 0.30            | 0.28            | 0.37              | 0.79              | 0.35               |
| MgO                 | 0.82              | 0.74            | 0.61            | 0.81            | 0.75            | 0.70              | 0.60              | 0.80               |
| Na2O                | 4.69              | 3.87            | 3.38            | 3.25            | 4.68            | 4.75              | 4.35              | 3.60               |
| K2O                 | 3.16              | 4.19            | 4.14            | 4.57            | 3.88            | 3.02              | 3.60              | 4.37               |
| TiO2                | 0.02              | 0.04            | 0.04            | 0.10            | 0.04            | 0.03              | 0.03              | 0.11               |
| P2O5                | 0.72              | 0.37            | 0.46            | 0.28            | 0.41            | 0.38              | 0.70              | 0.34               |
| MnO                 | 0.05              | 0.03            | 0.04            | 0.03            | 0.03            | 0.02              | 0.04              | 0.04               |
| H2O                 | 0.90              | 0.75            | 0.70            | 0.70            | 0.80            | 0.68              | 0.81              | 0.60               |
| Q                   | 32.50             | 35.35           | 37.62           | 36.96           | 30.72           | 35.03             | 33.13             | 35.13              |
| OR                  | 18.77             | 24.80           | 24.82           | 27.23           | 22.95           | 17.92             | 21.51             | 26.09              |
| AB                  | 39.85             | 32.76           | 28.98           | 27.70           | 39.59           | 40.31             | 37.19             | 30.74              |
| AN                  | 0.00              | 0.00            | 0.00            | 0.00            | 0.00            | 0.00              | 0.00              | 0.00               |
| C                   | 3.89              | 3.28            | 4.68            | 3.78            | 2.76            | 3.08              | 4.03              | 3.71               |
| EN                  | 2.05              | 1.84            | 1.54            | 2.03            | 1.87            | 1.75              | 1.51              | 2.01               |
| IL                  | 0.04              | 0.06            | 0.08            | 0.06            | 0.06            | 0.04              | 0.06              | 0.09               |
| HM                  | 1.11              | 1.04            | 1.19            | 1.51            | 1.10            | 0.97              | 0.89              | 1.37               |
| RU                  | 0.00              | 0.01            | 0.00            | 0.07            | 0.01            | 0.01              | 0.00              | 0.07               |
| AP                  | 1.68              | 0.86            | 1.08            | 0.65            | 0.95            | 0.88              | 1.64              | 0.80               |
| A/CNK               | 1.20              | 1.23            | 1.35            | 1.30            | 1.18            | 1.20              | 1.20              | 1.27               |
| TTDI                | 91.13             | 92.91           | 91.42           | 91.89           | 93.25           | 93.26             | 91.83             | 91.96              |
| Col. Ind.           | 3.31              | 2.95            | 2.82            | 3.61            | 3.03            | 2.76              | 2.50              | 3.47               |
| Ba                  | 25                | 16              | 8               | 77              | 11              | 11                | 41                | 70                 |
| Rb                  | 613               | 537             | 601             | 373             | 498             | 437               | 564               | 406                |
| Sr                  | 12                | 6               | 5               | 17              | 5               | 6                 | 18                | 17                 |
| Zr                  | 18                | 26              | 36              | 60              | 23              | 17                | 27                | 50                 |
| Nb                  | 34                | 16              | 20              | 12              | 22              | 18                | 29                | 18                 |
| V                   | 0                 | 0               | 3               | 0               | 0               | 0                 | 7                 | 9                  |
| Y                   | 28                | 26              | 20              | 23              | 25              | 19                | 28                | 26                 |
| Ga                  | 33                | 24              | 26              | 22              | 28              | 28                | 33                | 23                 |
| Cu                  | 0                 | 0               | 0               | 0               | 0               | 0                 | 7                 | 0                  |
| Zn                  | 44                | 32              | 68              | 54              | 49              | 39                | 40                | 40                 |
| Hf                  | 1                 | 0               | 1               | 2               | 1               | 1                 | 2                 | 3                  |
| Ta                  | 8.2               | 3.3             | 0.9             | 2.1             | 3.4             | 3.5               | 11.0              | 4.4                |
| Sc                  | 1.8               | 2.1             | 2.2             | 2.3             | 2.8             | 2.2               | 3.2               | 2.9                |
| La                  | 0                 | 0               | 2               | 6               | 0               | 0                 | 0                 | 9                  |
| Th                  | 1.5               | 2.4             | 3.1             | 5.2             | 1.8             | 1.3               | 1.5               | 6.2                |
| U                   | 1.9               | 2.1             | 2.9             | 3.8             | 5.8             | 1.8               | 2.3               | 7.0                |
| Li                  | 92                | 140             | 329             | 105             | 98              | 92                | 115               | 111                |
| F                   | 2065              | 2000            | 2900            | 1155            | 1685            | 1510              | 2500              | 1235               |
| As                  | 2.5               | 1.4             | 1.6             | 1.0             | 2.4             | 1.9               | 2.8               | 4.0                |
| Sn                  | 28                | 23              | 43              | 18              | 22              | 20                | 34                | 18                 |
| W                   | 8                 | 7               | 9               | 4               | 5               | 5                 | 9                 | 6                  |

# HALIFAX PLUTON (HP)

| SAMPLE                         | SAMPLE                         | D12-0077-2 | D12-0077-2C | D12-0082 | D12-0105 | D12-0130-4 | D12-0130-6 | D12-0130-8 |
|--------------------------------|--------------------------------|------------|-------------|----------|----------|------------|------------|------------|
| Rock Type                      | Rock Type                      | BGD        | BGD         | BGD      | BGD      | BGD        | BGD        | BGD        |
| Major Elements (wt %)          |                                |            |             |          |          |            |            |            |
| SiO <sub>2</sub>               | SiO <sub>2</sub>               | 68.16      | 69.19       | 66.89    | 69.17    | 67.09      | 66.47      | 67.55      |
| Al <sub>2</sub> O <sub>3</sub> | Al <sub>2</sub> O <sub>3</sub> | 15.45      | 15.23       | 15.50    | 14.88    | 15.90      | 15.86      | 15.90      |
| Fe <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | 4.41       | 3.55        | 4.40     | 3.62     | 4.04       | 4.53       | 4.24       |
| CaO                            | CaO                            | 1.81       | 0.96        | 1.89     | 1.53     | 1.93       | 2.33       | 1.93       |
| MgO                            | MgO                            | 1.50       | 1.63        | 1.72     | 1.59     | 1.88       | 1.96       | 1.57       |
| Na <sub>2</sub> O              | Na <sub>2</sub> O              | 3.51       | 3.66        | 3.81     | 4.13     | 3.87       | 3.56       | 3.55       |
| K <sub>2</sub> O               | K <sub>2</sub> O               | 3.64       | 4.69        | 3.99     | 3.90     | 3.99       | 3.64       | 3.94       |
| TiO <sub>2</sub>               | TiO <sub>2</sub>               | 0.62       | 0.48        | 0.66     | 0.51     | 0.59       | 0.67       | 0.59       |
| P <sub>2</sub> O <sub>5</sub>  | P <sub>2</sub> O <sub>5</sub>  | 0.21       | 0.18        | 0.22     | 0.14     | 0.20       | 0.21       | 0.19       |
| MnO                            | MnO                            | 0.10       | 0.08        | 0.09     | 0.09     | 0.09       | 0.08       | 0.09       |
| H <sub>2</sub> O               | H <sub>2</sub> O               | 0.60       | 0.70        | 0.70     | 1.10     | 0.60       | 0.50       | 0.70       |
| Normative Mineralogy           |                                |            |             |          |          |            |            |            |
| Q                              | Q                              | 28.45      | 26.05       | 23.65    | 25.06    | 23.02      | 24.67      | 25.99      |
| OR                             | OR                             | 21.66      | 27.84       | 23.80    | 23.17    | 23.70      | 21.68      | 23.41      |
| AB                             | AB                             | 29.87      | 31.07       | 32.50    | 35.10    | 32.88      | 30.33      | 30.17      |
| AN                             | AN                             | 7.65       | 3.60        | 8.00     | 6.70     | 8.30       | 10.26      | 8.37       |
| C                              | C                              | 2.96       | 2.82        | 2.02     | 1.42     | 2.19       | 2.34       | 2.75       |
| EN                             | EN                             | 3.76       | 4.07        | 4.32     | 3.98     | 4.70       | 4.91       | 3.93       |
| IL                             | IL                             | 0.22       | 0.17        | 0.19     | 0.19     | 0.19       | 0.17       | 0.19       |
| HM                             | HM                             | 4.44       | 3.56        | 4.44     | 3.64     | 4.06       | 4.56       | 4.26       |
| RU                             | RU                             | 0.51       | 0.39        | 0.56     | 0.41     | 0.49       | 0.58       | 0.49       |
| AP                             | AP                             | 0.49       | 0.42        | 0.51     | 0.33     | 0.47       | 0.49       | 0.44       |
| A/CNK                          | A/CNK                          | 1.19       | 1.19        | 1.11     | 1.08     | 1.12       | 1.13       | 1.17       |
| TTDI                           | TTDI                           | 79.98      | 84.96       | 79.95    | 83.33    | 79.60      | 76.68      | 79.57      |
| Col. Ind.                      | Col. Ind.                      | 8.41       | 7.81        | 8.95     | 7.81     | 8.95       | 9.65       | 8.38       |
| Trace Elements (ppm*)          |                                |            |             |          |          |            |            |            |
| Ba                             | Ba                             | 588        | 556         | 648      | 507      | 794        | 624        | 550        |
| Rb                             | Rb                             | 169        | 195         | 157      | 154      | 161        | 148        | 144        |
| Sr                             | Sr                             | 179        | 140         | 160      | 165      | 210        | 190        | 181        |
| Zr                             | Zr                             | 181        | 163         | 179      | 157      | 197        | 202        | 170        |
| Nb                             | Nb                             | 13         | 11          | 11       | 12       | 11         | 13         | 12         |
| V                              | V                              | 50         | 37          | 41       | 45       | 48         | 50         | 45         |
| Y                              | Y                              | 30         | 38          | 32       | 34       | 27         | 32         | 29         |
| Ga                             | Ga                             | 22         | 27          | 19       | 23       | 24         | 24         | 18         |
| Cu                             | Cu                             | 0          | 0           | 2        | 0        | 0          | 7          | 0          |
| Zn                             | Zn                             | 64         | 69          | 93       | 82       | 80         | 69         | 54         |
| Hf                             | Hf                             | 6          | 5           | 5        | 5        | 7          | 6          | 6          |
| Ta                             | Ta                             | 1.3        | 1.0         | 1.2      | 0.8      | 1.0        | 1.1        | 1.1        |
| Sc                             | Sc                             | 11.0       | 7.9         | 8.9      | 7.5      | 9.3        | 10.0       | 10.0       |
| La                             | La                             | 37         | 34          | 36       | 27       | 36         | 34         | 34         |
| Th                             | Th                             | 12.0       | 12.0        | 13.0     | 10.0     | 13.0       | 12.0       | 13.0       |
| U                              | U                              | 3.9        | 2.5         | 3.0      | 2.3      | 2.4        | 3.2        | 2.5        |
| Li                             | Li                             | 103        | 87          | 78       | 63       | 70         | 64         | 86         |
| F                              | F                              | 680        | 680         | 600      | 480      | 590        | 690        | 590        |
| As                             | As                             | 2.9        | 1.0         | 1.0      | 1.0      | 1.5        | 24.0       | 2.5        |
| Sn                             | Sn                             | 5          | 3           | 8        | 1        | 2          | 1          | 10         |
| W                              | W                              | 1          | 1           | 2        | 1        | 1          | 1          | 1          |

# HP cont.

| SAMPLE<br>Rock Type | D12-0134<br>BGD | D12-0134-C<br>BGD | D12-3133<br>BGD | D05-0003<br>CGLMG | D05-0015<br>CGLMG | D05-0015-2<br>CGLMG | D05-3051<br>CGLMG | D12-0030-3<br>CGLMG |
|---------------------|-----------------|-------------------|-----------------|-------------------|-------------------|---------------------|-------------------|---------------------|
| SiO2                | 67.63           | 67.71             | 68.01           | 73.23             | 72.14             | 72.09               | 73.41             | 72.53               |
| Al2O3               | 15.70           | 15.46             | 15.65           | 14.01             | 14.40             | 14.45               | 13.92             | 14.43               |
| Fe2O3               | 4.16            | 4.21              | 3.88            | 2.24              | 2.10              | 2.34                | 2.03              | 2.26                |
| CaO                 | 1.77            | 1.97              | 1.41            | 0.73              | 0.92              | 0.87                | 0.84              | 0.90                |
| MgO                 | 1.56            | 1.65              | 1.67            | 0.85              | 1.21              | 1.21                | 1.03              | 0.86                |
| Na2O                | 3.42            | 3.36              | 3.81            | 3.39              | 3.93              | 3.44                | 3.64              | 3.36                |
| K2O                 | 3.77            | 4.00              | 4.27            | 4.35              | 4.29              | 4.68                | 4.43              | 4.82                |
| TiO2                | 0.59            | 0.60              | 0.53            | 0.21              | 0.23              | 0.29                | 0.21              | 0.28                |
| P2O5                | 0.18            | 0.21              | 0.19            | 0.21              | 0.18              | 0.25                | 0.19              | 0.24                |
| MNO                 | 0.08            | 0.10              | 0.08            | 0.07              | 0.05              | 0.05                | 0.06              | 0.04                |
| H2O                 | 0.80            | 0.50              | 0.50            | 0.60              | 0.50              | 0.40                | 0.30              | 0.70                |
| Q                   | 28.00           | 26.95             | 24.64           | 34.86             | 29.74             | 31.29               | 32.55             | 32.08               |
| OR                  | 22.56           | 23.83             | 25.38           | 25.91             | 25.52             | 27.77               | 26.27             | 28.59               |
| AB                  | 29.27           | 28.64             | 32.40           | 28.89             | 33.43             | 29.20               | 30.87             | 28.51               |
| AN                  | 7.69            | 8.46              | 5.78            | 2.26              | 3.40              | 2.69                | 2.93              | 2.90                |
| C                   | 3.24            | 2.54              | 2.66            | 2.92              | 2.06              | 2.75                | 2.07              | 2.63                |
| EN                  | 3.93            | 4.14              | 4.18            | 2.13              | 3.03              | 3.02                | 2.57              | 2.15                |
| IL                  | 0.17            | 0.22              | 0.17            | 0.15              | 0.11              | 0.11                | 0.13              | 0.09                |
| HM                  | 4.21            | 4.24              | 3.90            | 2.26              | 2.11              | 2.35                | 2.03              | 2.27                |
| RU                  | 0.51            | 0.49              | 0.44            | 0.13              | 0.17              | 0.23                | 0.14              | 0.24                |
| AP                  | 0.42            | 0.49              | 0.44            | 0.49              | 0.42              | 0.58                | 0.44              | 0.56                |
| A/CNK               | 1.21            | 1.15              | 1.16            | 1.21              | 1.13              | 1.17                | 1.13              | 1.17                |
| TTDI                | 79.83           | 79.42             | 82.42           | 89.66             | 88.69             | 88.27               | 89.68             | 89.18               |
| Col. Ind.           | 8.31            | 8.60              | 8.25            | 4.54              | 5.25              | 5.48                | 4.73              | 4.50                |
| Ba                  | 534             | 541               | 537             | 178               | 234               | 321                 | 272               | 319                 |
| Rb                  | 152             | 174               | 188             | 253               | 226               | 258                 | 237               | 261                 |
| Sr                  | 178             | 166               | 138             | 59                | 84                | 78                  | 67                | 78                  |
| Zr                  | 174             | 177               | 173             | 81                | 90                | 116                 | 91                | 103                 |
| Nb                  | 11              | 12                | 13              | 11                | 10                | 12                  | 11                | 11                  |
| V                   | 43              | 43                | 36              | 12                | 18                | 16                  | 14                | 21                  |
| Y                   | 29              | 32                | 33              | 24                | 26                | 22                  | 23                | 22                  |
| Ga                  | 19              | 24                | 18              | 21                | 23                | 24                  | 21                | 18                  |
| Cu                  | 0               | 5                 | 0               | 0                 | 0                 | 0                   | 0                 | 0                   |
| Zn                  | 57              | 65                | 72              | 44                | 43                | 47                  | 40                | 44                  |
| Hf                  | 6               | 6                 | 6               | 2                 | 3                 | 4                   | 3                 | 3                   |
| Ta                  | 1.2             | 1.1               | 1.4             | 1.8               | 1.3               | 1.4                 | 1.4               | 1.5                 |
| Sc                  | 10.0            | 11.0              | 8.8             | 4.3               | 4.7               | 4.5                 | 4.3               | 4.3                 |
| La                  | 34              | 33                | 36              | 14                | 16                | 22                  | 16                | 17                  |
| Th                  | 12.0            | 11.0              | 15.0            | 7.7               | 8.7               | 11.0                | 8.5               | 8.8                 |
| U                   | 3.4             | 3.0               | 3.4             | 5.9               | 3.3               | 7.8                 | 3.0               | 6.9                 |
| Li                  | 69              | 59                | 77              | 82                | 95                | 95                  | 99                | 106                 |
| F                   | 530             | 860               | 760             | 530               | 610               | 890                 | 560               | 630                 |
| As                  | 1.6             | 8.7               | 1.6             | 2.8               | 2.1               | 3.6                 | 1.4               | 3.9                 |
| Sn                  | 7               | 4                 | 5               | 12                | 3                 | 8                   | 6                 | 7                   |
| W                   | 1               | 1                 | 1               | 1                 | 1                 | 1                   | 2                 | 1                   |

HP cont.

| SAMPLE<br>Rock Type | D12-0030-C<br>CGLMG | D12-0043<br>CGLMG | D12-0050<br>CGLMG | D12-0051<br>CGLMG | D12-0052<br>CGLMG | D12-0069<br>CGLMG | D12-0081<br>CGLMG | D12-0103-1<br>CGLMG |
|---------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|---------------------|
| SiO2                | 70.31               | 71.65             | 72.97             | 73.55             | 73.55             | 72.65             | 72.59             | 71.81               |
| Al2O3               | 15.57               | 14.27             | 14.35             | 14.56             | 14.45             | 14.95             | 14.15             | 14.57               |
| Fe2O3               | 2.07                | 2.88              | 2.14              | 1.88              | 1.80              | 1.92              | 2.81              | 2.35                |
| CaO                 | 0.96                | 1.00              | 0.59              | 0.51              | 0.53              | 0.50              | 0.63              | 0.88                |
| MgO                 | 1.12                | 1.05              | 0.77              | 0.58              | 0.64              | 0.66              | 0.85              | 0.90                |
| Na2O                | 4.18                | 3.01              | 3.14              | 3.30              | 3.38              | 3.30              | 3.29              | 2.99                |
| K2O                 | 5.02                | 4.72              | 4.89              | 4.63              | 4.83              | 4.84              | 4.37              | 4.89                |
| TiO2                | 0.24                | 0.37              | 0.21              | 0.13              | 0.14              | 0.17              | 0.28              | 0.27                |
| P2O5                | 0.23                | 0.23              | 0.19              | 0.21              | 0.23              | 0.28              | 0.18              | 0.21                |
| MnO                 | 0.04                | 0.06              | 0.07              | 0.08              | 0.06              | 0.05              | 0.06              | 0.05                |
| H2O                 | 0.40                | 0.70              | 0.70              | 0.70              | 0.50              | 0.70              | 0.70              | 0.50                |
| Q                   | 23.75               | 33.25             | 34.33             | 35.46             | 34.08             | 33.88             | 34.88             | 33.41               |
| OR                  | 29.77               | 28.13             | 29.12             | 27.54             | 28.68             | 28.82             | 26.05             | 29.24               |
| AB                  | 35.46               | 25.66             | 26.75             | 28.08             | 28.71             | 28.11             | 28.06             | 25.57               |
| AN                  | 3.27                | 3.48              | 1.69              | 1.16              | 1.13              | 0.65              | 1.96              | 3.02                |
| C                   | 2.07                | 2.96              | 3.29              | 3.71              | 3.26              | 4.07              | 3.32              | 3.29                |
| EN                  | 2.80                | 2.63              | 1.93              | 1.45              | 1.60              | 1.65              | 2.13              | 2.27                |
| IL                  | 0.09                | 0.13              | 0.15              | 0.17              | 0.13              | 0.11              | 0.13              | 0.11                |
| HM                  | 2.08                | 2.90              | 2.15              | 1.89              | 1.81              | 1.93              | 2.83              | 2.38                |
| RU                  | 0.20                | 0.30              | 0.13              | 0.04              | 0.07              | 0.11              | 0.21              | 0.22                |
| AP                  | 0.53                | 0.54              | 0.44              | 0.49              | 0.54              | 0.65              | 0.42              | 0.49                |
| A/CNK               | 1.11                | 1.20              | 1.24              | 1.28              | 1.23              | 1.29              | 1.25              | 1.23                |
| TTDI                | 88.98               | 87.05             | 90.20             | 91.08             | 91.47             | 90.82             | 88.99             | 88.23               |
| Col. Ind.           | 4.96                | 5.67              | 4.24              | 3.52              | 3.54              | 3.70              | 5.10              | 4.75                |
| Ba                  | 288                 | 374               | 216               | 127               | 104               | 173               | 222               | 242                 |
| Rb                  | 246                 | 220               | 287               | 339               | 330               | 340               | 225               | 234                 |
| Sr                  | 89                  | 105               | 60                | 28                | 27                | 37                | 58                | 69                  |
| Zr                  | 102                 | 127               | 80                | 64                | 59                | 74                | 117               | 102                 |
| Nb                  | 11                  | 13                | 11                | 11                | 11                | 14                | 11                | 11                  |
| V                   | 14                  | 21                | 10                | 8                 | 5                 | 8                 | 17                | 13                  |
| Y                   | 26                  | 25                | 24                | 23                | 21                | 19                | 34                | 25                  |
| Ga                  | 25                  | 21                | 21                | 23                | 19                | 22                | 20                | 20                  |
| Cu                  | 1                   | 3                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                   |
| Zn                  | 46                  | 65                | 48                | 54                | 50                | 51                | 33                | 43                  |
| Hf                  | 3                   | 3                 | 3                 | 2                 | 1                 | 2                 | 4                 | 4                   |
| Ta                  | 1.3                 | 1.3               | 1.9               | 2.3               | 2.6               | 2.6               | 1.7               | 1.2                 |
| Sc                  | 4.2                 | 5.8               | 4.3               | 3.5               | 3.6               | 3.7               | 5.6               | 4.3                 |
| La                  | 20                  | 23                | 14                | 9                 | 10                | 12                | 23                | 19                  |
| Th                  | 10.0                | 11.0              | 8.2               | 7.0               | 6.5               | 6.7               | 12.0              | 10.0                |
| U                   | 6.1                 | 3.4               | 4.6               | 3.2               | 2.9               | 8.1               | 3.3               | 6.1                 |
| Li                  | 63                  | 80                | 101               | 136               | 137               | 157               | 63                | 58                  |
| F                   | 675                 | 900               | 800               | 990               | 945               | 1080              | 560               | 710                 |
| As                  | 3.5                 | 2.7               | 1.0               | 1.9               | 1.6               | 3.0               | 1.6               | 2.1                 |
| Sn                  | 5                   | 4                 | 14                | 21                | 16                | 18                | 16                | 12                  |
| W                   | 1                   | 1                 | 3                 | 6                 | 2                 | 1                 | 1                 | 1                   |

## HP cont.

| SAMPLE<br>Rock Type | D12-0103-2<br>CGLMG | D12-0103-3<br>CGLMG | D12-3008<br>CGLMG | D12-3077-3<br>CGLMG | D12-3082<br>CGLMG | D12-3083<br>CGLMG | D12-3111<br>CGLMG | D12-3114<br>CGLMG |
|---------------------|---------------------|---------------------|-------------------|---------------------|-------------------|-------------------|-------------------|-------------------|
| SiO2                | 72.12               | 73.10               | 73.51             | 74.41               | 73.15             | 73.46             | 71.77             | 72.52             |
| Al2O3               | 14.50               | 14.53               | 14.06             | 13.86               | 14.01             | 14.13             | 14.70             | 14.55             |
| Fe2O3               | 2.17                | 1.74                | 2.00              | 1.74                | 1.99              | 1.89              | 1.94              | 2.03              |
| CaO                 | 0.76                | 0.43                | 0.65              | 0.52                | 0.66              | 0.68              | 0.67              | 0.79              |
| MgO                 | 0.77                | 0.69                | 0.74              | 0.78                | 0.99              | 1.03              | 1.08              | 0.79              |
| Na2O                | 3.39                | 3.14                | 3.11              | 3.27                | 3.72              | 4.13              | 4.13              | 2.96              |
| K2O                 | 4.77                | 4.74                | 4.47              | 4.51                | 4.38              | 4.63              | 4.84              | 4.60              |
| TiO2                | 0.24                | 0.14                | 0.18              | 0.16                | 0.18              | 0.17              | 0.22              | 0.19              |
| P2O5                | 0.24                | 0.27                | 0.26              | 0.25                | 0.19              | 0.16              | 0.26              | 0.18              |
| MnO                 | 0.05                | 0.06                | 0.05              | 0.04                | 0.06              | 0.07              | 0.04              | 0.07              |
| H2O                 | 0.60                | 0.60                | 0.50              | 0.40                | 0.50              | 0.50              | 0.60              | 0.80              |
| Q                   | 32.35               | 35.91               | 36.89             | 36.71               | 32.60             | 29.06             | 26.99             | 35.79             |
| OR                  | 28.50               | 28.37               | 26.70             | 26.80               | 26.08             | 27.29             | 28.73             | 27.57             |
| AB                  | 28.97               | 26.88               | 26.57             | 27.79               | 31.69             | 34.82             | 35.07             | 25.38             |
| AN                  | 2.22                | 0.37                | 1.54              | 0.95                | 2.04              | 2.32              | 1.63              | 2.78              |
| C                   | 2.98                | 4.14                | 3.58              | 3.26                | 2.42              | 1.46              | 2.08              | 3.74              |
| EN                  | 1.94                | 1.74                | 1.86              | 1.95                | 2.48              | 2.56              | 2.70              | 1.99              |
| IL                  | 0.11                | 0.13                | 0.11              | 0.09                | 0.13              | 0.15              | 0.09              | 0.15              |
| HM                  | 2.19                | 1.76                | 2.02              | 1.75                | 2.00              | 1.88              | 1.95              | 2.06              |
| RU                  | 0.19                | 0.07                | 0.12              | 0.12                | 0.11              | 0.09              | 0.18              | 0.11              |
| AP                  | 0.56                | 0.63                | 0.61              | 0.58                | 0.44              | 0.37              | 0.61              | 0.42              |
| A/CNK               | 1.20                | 1.31                | 1.26              | 1.24                | 1.16              | 1.08              | 1.11              | 1.29              |
| TTDI                | 89.82               | 91.15               | 90.16             | 91.30               | 90.37             | 91.17             | 90.78             | 88.74             |
| Col. Ind.           | 4.24                | 3.63                | 3.99              | 3.79                | 4.61              | 4.59              | 4.73              | 4.20              |
| Ba                  | 245                 | 123                 | 155               | 147                 | 163               | 146               | 249               | 176               |
| Rb                  | 266                 | 350                 | 299               | 282                 | 261               | 278               | 294               | 253               |
| Sr                  | 68                  | 27                  | 45                | 39                  | 52                | 46                | 58                | 53                |
| Zr                  | 93                  | 64                  | 78                | 72                  | 82                | 76                | 94                | 84                |
| Nb                  | 11                  | 13                  | 12                | 12                  | 10                | 10                | 13                | 11                |
| V                   | 13                  | 4                   | 10                | 8                   | 13                | 9                 | 12                | 12                |
| Y                   | 22                  | 18                  | 21                | 18                  | 28                | 28                | 20                | 24                |
| Ga                  | 20                  | 24                  | 24                | 21                  | 24                | 20                | 24                | 22                |
| Cu                  | 3                   | 0                   | 0                 | 0                   | 0                 | 0                 | 0                 | 0                 |
| Zn                  | 44                  | 54                  | 43                | 63                  | 88                | 80                | 77                | 50                |
| Hf                  | 3                   | 1                   | 3                 | 3                   | 2                 | 3                 | 3                 | 3                 |
| Ta                  | 1.7                 | 2.8                 | 1.9               | 2.1                 | 1.6               | 1.5               | 2.0               | 1.7               |
| Sc                  | 3.9                 | 3.3                 | 3.9               | 3.6                 | 3.7               | 3.4               | 3.5               | 4.8               |
| La                  | 16                  | 11                  | 14                | 16                  | 12                | 11                | 17                | 17                |
| Th                  | 8.2                 | 7.0                 | 7.4               | 9.3                 | 7.4               | 7.2               | 10.0              | 8.7               |
| U                   | 5.8                 | 5.0                 | 5.8               | 12.0                | 4.2               | 4.1               | 5.9               | 3.1               |
| Li                  | 76                  | 123                 | 127               | 89                  | 88                | 105               | 88                | 73                |
| F                   | 640                 | 1100                | 930               | 760                 | 840               | 870               | 830               | 660               |
| As                  | 3.1                 | 10.0                | 1.5               | 7.9                 | 3.2               | 2.6               | 2.1               | 1.6               |
| Sn                  | 13                  | 24                  | 13                | 14                  | 10                | 12                | 9                 | 13                |
| W                   | 2                   | 6                   | 2                 | 3                   | 1                 | 1                 | 8                 | 2                 |



HP cont.

| SAMPLE<br>Rock Type | D12-3128-C<br>CGLMG | D12-3136<br>CGLMG | D12-3136-2<br>CGLMG | D12-0001<br>FGLMG | D12-0004<br>FGLMG | D12-0004-2<br>FGLMG | D12-0044<br>FGLMG | D12-0066<br>FGLMG |
|---------------------|---------------------|-------------------|---------------------|-------------------|-------------------|---------------------|-------------------|-------------------|
| SiO2                | 72.98               | 74.17             | 74.68               | 76.08             | 74.31             | 73.68               | 74.42             | 75.14             |
| Al2O3               | 14.57               | 13.64             | 13.83               | 12.94             | 14.36             | 14.67               | 14.48             | 14.11             |
| Fe2O3               | 1.59                | 1.52              | 1.44                | 1.64              | 2.20              | 2.02                | 1.14              | 1.34              |
| CaO                 | 0.55                | 0.32              | 0.31                | 0.28              | 0.48              | 0.59                | 0.34              | 0.36              |
| MgO                 | 0.92                | 0.68              | 0.95                | 0.63              | 0.75              | 0.83                | 0.40              | 0.52              |
| Na2O                | 4.06                | 3.28              | 3.61                | 2.70              | 3.20              | 3.53                | 3.99              | 3.66              |
| K2O                 | 4.67                | 4.48              | 4.50                | 4.34              | 4.68              | 4.43                | 4.10              | 4.31              |
| TiO2                | 0.13                | 0.09              | 0.09                | 0.10              | 0.22              | 0.22                | 0.05              | 0.08              |
| P2O5                | 0.25                | 0.19              | 0.20                | 0.18              | 0.19              | 0.26                | 0.33              | 0.26              |
| MnO                 | 0.04                | 0.06              | 0.06                | 0.05              | 0.06              | 0.06                | 0.04              | 0.04              |
| H2O                 | 0.40                | 0.70              | 0.60                | 1.00              | 0.60              | 0.80                | 0.70              | 0.70              |
| Q                   | 29.70               | 37.35             | 35.04               | 43.18             | 36.00             | 34.31               | 35.12             | 36.59             |
| OR                  | 27.69               | 26.92             | 26.71               | 25.95             | 27.56             | 26.13               | 24.40             | 25.54             |
| AB                  | 34.43               | 28.19             | 30.64               | 23.09             | 26.95             | 29.78               | 33.97             | 31.02             |
| AN                  | 1.09                | 0.35              | 0.23                | 0.21              | 1.13              | 1.22                | 0.00              | 0.08              |
| C                   | 2.44                | 3.32              | 2.94                | 3.76              | 3.59              | 3.60                | 3.50              | 3.40              |
| EN                  | 2.30                | 1.72              | 2.37                | 1.59              | 1.86              | 2.06                | 1.00              | 1.30              |
| IL                  | 0.09                | 0.13              | 0.13                | 0.11              | 0.13              | 0.13                | 0.09              | 0.09              |
| HM                  | 1.59                | 1.54              | 1.44                | 1.66              | 2.19              | 2.01                | 1.15              | 1.34              |
| RU                  | 0.09                | 0.02              | 0.02                | 0.04              | 0.15              | 0.15                | 0.00              | 0.04              |
| AP                  | 0.58                | 0.45              | 0.47                | 0.42              | 0.44              | 0.60                | 0.77              | 0.60              |
| A/CNK               | 1.14                | 1.26              | 1.22                | 1.34              | 1.28              | 1.26                | 1.25              | 1.24              |
| TTDI                | 91.82               | 92.47             | 92.39               | 92.21             | 90.51             | 90.22               | 93.49             | 93.16             |
| Col. Ind.           | 3.98                | 3.40              | 3.95                | 3.35              | 4.18              | 4.20                | 2.24              | 2.73              |
| Ba                  | 152                 | 74                | 68                  | 78                | 170               | 240                 | 33                | 50                |
| Rb                  | 323                 | 303               | 303                 | 248               | 273               | 286                 | 499               | 427               |
| Sr                  | 38                  | 23                | 20                  | 18                | 44                | 62                  | 7                 | 19                |
| Zr                  | 61                  | 48                | 52                  | 63                | 89                | 79                  | 34                | 37                |
| Nb                  | 11                  | 7                 | 9                   | 8                 | 12                | 11                  | 14                | 13                |
| V                   | 4                   | 8                 | 3                   | 3                 | 13                | 12                  | 3                 | 3                 |
| Y                   | 18                  | 19                | 22                  | 19                | 28                | 24                  | 14                | 16                |
| Ga                  | 23                  | 20                | 24                  | 19                | 21                | 20                  | 24                | 20                |
| Cu                  | 0                   | 0                 | 0                   | 2                 | 2                 | 2                   | 0                 | 0                 |
| Zn                  | 38                  | 34                | 34                  | 37                | 136               | 41                  | 44                | 32                |
| Hf                  | 2                   | 2                 | 2                   | 2                 | 2                 | 2                   | 1                 | 1                 |
| Ta                  | 2.2                 | 2.3               | 2.5                 | 1.7               | 1.8               | 4.8                 | 3.8               | 3.5               |
| Sc                  | 2.6                 | 2.7               | 3.0                 | 1.8               | 4.3               | 3.7                 | 2.3               | 4.1               |
| La                  | 10                  | 8                 | 7                   | 8                 | 15                | 13                  | 2                 | 5                 |
| Th                  | 5.2                 | 5.3               | 5.0                 | 5.1               | 7.6               | 5.9                 | 1.6               | 3.5               |
| U                   | 6.9                 | 10.0              | 11.0                | 3.4               | 3.9               | 4.5                 | 19.0              | 5.2               |
| Li                  | 103                 | 62                | 84                  | 62                | 112               | 134                 | 230               | 157               |
| F                   | 925                 | 450               | 430                 | 580               | 610               | 630                 | 1400              | 1080              |
| As                  | 3.5                 | 18.0              | 3.0                 | 7.9               | 4.1               | 4.9                 | 20.0              | 1.4               |
| Sn                  | 17                  | 9                 | 10                  | 13                | 10                | 12                  | 27                | 24                |
| W                   | 5                   | 2                 | 2                   | 5                 | 3                 | 2                   | 8                 | 6                 |

# HP cont.

| SAMPLE<br>Rock Type | D12-0117<br>FGLMG | D12-0121-C<br>FGLMG | D12-0122<br>FGLMG | D12-0122-4<br>FGLMG | D12-0140<br>FGLMG | D12-0141<br>FGLMG | D12-3000<br>FGLMG | D12-3002<br>FGLMG |
|---------------------|-------------------|---------------------|-------------------|---------------------|-------------------|-------------------|-------------------|-------------------|
| SiO2                | 74.24             | 74.76               | 75.32             | 75.30               | 74.85             | 74.76             | 74.42             | 75.67             |
| Al2O3               | 14.15             | 14.03               | 13.79             | 14.14               | 13.93             | 13.92             | 13.82             | 13.00             |
| Fe2O3               | 1.57              | 1.17                | 1.50              | 0.99                | 1.20              | 1.54              | 1.69              | 2.07              |
| CaO                 | 0.34              | 0.34                | 0.39              | 0.47                | 0.35              | 0.30              | 0.28              | 0.39              |
| MgO                 | 0.65              | 0.86                | 0.58              | 0.44                | 0.54              | 0.65              | 0.92              | 1.07              |
| Na2O                | 3.33              | 3.41                | 3.35              | 3.61                | 3.41              | 3.41              | 3.41              | 2.98              |
| K2O                 | 4.63              | 4.49                | 4.27              | 4.49                | 4.75              | 4.60              | 4.58              | 4.12              |
| TiO2                | 0.12              | 0.06                | 0.08              | 0.03                | 0.06              | 0.15              | 0.11              | 0.16              |
| P2O5                | 0.22              | 0.21                | 0.21              | 0.14                | 0.27              | 0.21              | 0.24              | 0.21              |
| MnO                 | 0.05              | 0.05                | 0.06              | 0.04                | 0.04              | 0.04              | 0.06              | 0.08              |
| H2O                 | 0.70              | 0.60                | 0.70              | 0.60                | 0.50              | 0.80              | 0.70              | 0.90              |
| Q                   | 36.31             | 36.53               | 38.54             | 35.96               | 36.23             | 36.44             | 35.82             | 40.82             |
| OR                  | 27.58             | 26.72               | 25.37             | 26.65               | 28.26             | 27.32             | 27.21             | 24.43             |
| AB                  | 28.37             | 29.03               | 28.47             | 30.65               | 29.02             | 28.97             | 28.98             | 25.28             |
| AN                  | 0.25              | 0.31                | 0.56              | 1.42                | 0.00              | 0.11              | 0.00              | 0.56              |
| C                   | 3.59              | 3.46                | 3.46              | 2.83                | 3.19              | 3.30              | 3.26              | 3.44              |
| EN                  | 1.63              | 2.16                | 1.45              | 1.10                | 1.35              | 1.63              | 2.30              | 2.67              |
| IL                  | 0.11              | 0.11                | 0.13              | 0.06                | 0.09              | 0.09              | 0.13              | 0.17              |
| HM                  | 1.58              | 1.18                | 1.51              | 0.96                | 1.21              | 1.55              | 1.70              | 2.08              |
| RU                  | 0.06              | 0.00                | 0.01              | 0.00                | 0.02              | 0.11              | 0.04              | 0.07              |
| AP                  | 0.51              | 0.49                | 0.49              | 0.33                | 0.63              | 0.49              | 0.56              | 0.49              |
| A/CNK               | 1.27              | 1.27                | 1.27              | 1.21                | 1.22              | 1.25              | 1.25              | 1.29              |
| TTDI                | 92.26             | 92.29               | 92.39             | 93.26               | 93.52             | 92.73             | 92.01             | 90.52             |
| Col. Ind.           | 3.32              | 3.44                | 3.09              | 2.16                | 2.65              | 3.26              | 4.13              | 4.92              |
| Ba                  | 96                | 23                  | 40                | 9                   | 16                | 53                | 84                | 115               |
| Rb                  | 279               | 339                 | 319               | 205                 | 277               | 272               | 369               | 254               |
| Sr                  | 26                | 9                   | 16                | 10                  | 13                | 24                | 20                | 28                |
| Zr                  | 61                | 39                  | 45                | 27                  | 32                | 63                | 59                | 73                |
| Nb                  | 10                | 8                   | 9                 | 5                   | 7                 | 12                | 12                | 11                |
| V                   | 6                 | 0                   | 7                 | 2                   | 1                 | 6                 | 7                 | 7                 |
| Y                   | 20                | 18                  | 17                | 14                  | 12                | 28                | 25                | 23                |
| Ga                  | 20                | 24                  | 21                | 14                  | 24                | 19                | 20                | 18                |
| Cu                  | 0                 | 0                   | 4                 | 0                   | 0                 | 0                 | 0                 | 0                 |
| Zn                  | 44                | 43                  | 43                | 17                  | 23                | 45                | 30                | 39                |
| Hf                  | 2                 | 1                   | 1                 | 1                   | 1                 | 2                 | 1                 | 3                 |
| Ta                  | 1.9               | 2.1                 | 2.0               | 1.2                 | 1.6               | 2.3               | 2.3               | 1.9               |
| Sc                  | 3.1               | 2.3                 | 2.7               | 1.3                 | 0.8               | 3.7               | 2.9               | 5.7               |
| La                  | 8                 | 3                   | 5                 | 3                   | 3                 | 9                 | 7                 | 15                |
| Th                  | 5.6               | 3.4                 | 4.2               | 2.1                 | 2.1               | 5.6               | 5.1               | 8.6               |
| U                   | 10.0              | 8.3                 | 11.0              | 13.0                | 15.0              | 6.5               | 5.0               | 4.2               |
| Li                  | 79                | 98                  | 90                | 68                  | 79                | 37                | 64                | 72                |
| F                   | 480               | 765                 | 660               | 140                 | 540               | 290               | 405               | 540               |
| As                  | 1.5               | 1.7                 | 4.8               | 1.6                 | 3.1               | 2.2               | 1.5               | 1.1               |
| Sn                  | 13                | 23                  | 19                | 12                  | 14                | 11                | 7                 | 9                 |
| W                   | 3                 | 5                   | 4                 | 1                   | 4                 | 6                 | 2                 | 42                |

HP cont.

| SAMPLE<br>Rock Type            | D12-3070-3<br>FGLMG | D12-3112<br>FGLMG | D12-3120<br>FGLMG | D12-3149<br>FGLMG | D12-3151<br>FGLMG | D12-3154<br>FGLMG | D12-0100<br>FGLMG <sub>e</sub> | D12-0121<br>FGLMG <sub>e</sub> |
|--------------------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------------------|--------------------------------|
| SiO <sub>2</sub>               | 74.21               | 72.64             | 74.85             | 74.45             | 73.67             | 74.87             | 75.08                          | 74.58                          |
| Al <sub>2</sub> O <sub>3</sub> | 14.57               | 15.12             | 14.24             | 14.31             | 14.21             | 13.77             | 14.23                          | 14.40                          |
| Fe <sub>2</sub> O <sub>3</sub> | 1.47                | 1.39              | 1.20              | 1.23              | 1.80              | 1.32              | 1.21                           | 1.32                           |
| CaO                            | 0.41                | 0.47              | 0.31              | 0.33              | 0.42              | 0.29              | 0.28                           | 0.29                           |
| MgO                            | 0.67                | 0.80              | 0.56              | 0.64              | 0.77              | 0.61              | 0.54                           | 0.43                           |
| Na <sub>2</sub> O              | 2.23                | 3.45              | 3.85              | 3.55              | 3.40              | 3.30              | 3.75                           | 3.63                           |
| K <sub>2</sub> O               | 4.20                | 4.67              | 4.20              | 4.34              | 4.57              | 4.63              | 4.38                           | 4.10                           |
| TiO <sub>2</sub>               | 0.13                | 0.14              | 0.05              | 0.06              | 0.17              | 0.08              | 0.05                           | 0.04                           |
| P <sub>2</sub> O <sub>5</sub>  | 0.35                | 0.37              | 0.26              | 0.26              | 0.26              | 0.14              | 0.17                           | 0.27                           |
| MnO                            | 0.06                | 0.03              | 0.06              | 0.05              | 0.05              | 0.05              | 0.08                           | 0.06                           |
| H <sub>2</sub> O               | 0.90                | 0.80              | 0.70              | 0.40              | 0.70              | 0.70              | 0.60                           | 0.70                           |
| Q                              | 44.89               | 33.79             | 35.67             | 36.50             | 35.31             | 37.15             | 35.65                          | 37.42                          |
| OR                             | 25.26               | 27.87             | 24.94             | 25.87             | 27.22             | 27.65             | 25.97                          | 24.45                          |
| AB                             | 19.18               | 29.46             | 32.70             | 30.27             | 28.96             | 28.19             | 31.80                          | 30.96                          |
| AN                             | 0.00                | 0.00              | 0.00              | 0.00              | 0.38              | 0.53              | 0.28                           | 0.00                           |
| C                              | 6.46                | 4.43              | 3.37              | 3.80              | 3.55              | 3.16              | 3.22                           | 4.02                           |
| EN                             | 1.70                | 2.01              | 1.40              | 1.61              | 1.93              | 1.53              | 1.35                           | 1.08                           |
| IL                             | 0.13                | 0.06              | 0.10              | 0.11              | 0.11              | 0.11              | 0.10                           | 0.08                           |
| HM                             | 1.49                | 1.40              | 1.17              | 1.24              | 1.81              | 1.33              | 1.13                           | 1.28                           |
| RU                             | 0.06                | 0.11              | 0.00              | 0.00              | 0.11              | 0.02              | 0.00                           | 0.00                           |
| AP                             | 0.83                | 0.87              | 0.61              | 0.61              | 0.61              | 0.33              | 0.40                           | 0.63                           |
| A/CNK                          | 1.63                | 1.31              | 1.24              | 1.28              | 1.26              | 1.26              | 1.25                           | 1.32                           |
| TTDI                           | 89.33               | 91.12             | 93.31             | 92.64             | 91.49             | 92.98             | 93.41                          | 92.84                          |
| Col. Ind.                      | 3.32                | 3.48              | 2.72              | 2.95              | 3.85              | 2.97              | 2.69                           | 2.51                           |
| Ba                             | 58                  | 367               | 10                | 11                | 129               | 54                | 28                             | 0                              |
| Rb                             | 470                 | 220               | 424               | 406               | 334               | 222               | 327                            | 550                            |
| Sr                             | 20                  | 59                | 7                 | 7                 | 37                | 19                | 14                             | 6                              |
| Zr                             | 52                  | 65                | 40                | 43                | 73                | 57                | 42                             | 39                             |
| Nb                             | 16                  | 12                | 11                | 12                | 13                | 8                 | 9                              | 15                             |
| V                              | 7                   | 3                 | 3                 | 3                 | 8                 | 0                 | 3                              | 2                              |
| Y                              | 18                  | 14                | 18                | 18                | 18                | 20                | 21                             | 18                             |
| Ga                             | 23                  | 20                | 22                | 23                | 21                | 19                | 19                             | 24                             |
| Cu                             | 3                   | 0                 | 0                 | 0                 | 0                 | 3                 | 1                              | 5                              |
| Zn                             | 49                  | 42                | 37                | 99                | 39                | 31                | 34                             | 65                             |
| Hf                             | 2                   | 1                 | 1                 | 1                 | 2                 | 2                 | 1                              | 1                              |
| Ta                             | 4.0                 | 1.8               | 3.2               | 2.7               | 2.1               | 1.5               | 2.4                            | 5.5                            |
| Sc                             | 3.9                 | 3.0               | 2.6               | 2.6               | 3.5               | 3.0               | 3.1                            | 3.2                            |
| La                             | 8                   | 10                | 4                 | 3                 | 13                | 7                 | 5                              | 2                              |
| Th                             | 3.7                 | 3.9               | 3.7               | 3.7               | 6.5               | 5.4               | 4.3                            | 3.4                            |
| U                              | 12.0                | 3.1               | 5.4               | 8.2               | 10.0              | 6.9               | 9.1                            | 20.0                           |
| Li                             | 121                 | 91                | 104               | 96                | 103               | 18                | 172                            | 280                            |
| F                              | 1350                | 640               | 1050              | 850               | 870               | 250               | 560                            | 1200                           |
| As                             | 29.0                | 1.7               | 4.7               | 3.8               | 4.2               | 8.6               | 1.2                            | 5.9                            |
| Sn                             | 36                  | 14                | 28                | 20                | 21                | 12                | 22                             | 48                             |
| W                              | 9                   | 5                 | 6                 | 4                 | 6                 | 2                 | 4                              | 10                             |

# HP cont.

| SAMPLE<br>Rock Type | D12-0121-1<br>FGLMGe | D12-0121-C2<br>FGLMGe | D12-0074<br>FGLMGp | D12-0074-2<br>FGLMGp | D12-3009<br>FGLMGp | D12-3076<br>FGLMGp | D05-0002<br>MBMG | D05-0005<br>MBMG |
|---------------------|----------------------|-----------------------|--------------------|----------------------|--------------------|--------------------|------------------|------------------|
| SiO2                | 75.29                | 75.22                 | 73.59              | 70.59                | 71.97              | 71.92              | 71.90            | 69.11            |
| Al2O3               | 14.16                | 14.10                 | 14.33              | 15.17                | 14.85              | 14.72              | 14.33            | 15.25            |
| Fe2O3               | 1.11                 | 1.31                  | 2.04               | 2.86                 | 2.15               | 2.39               | 2.53             | 3.31             |
| CaO                 | 0.26                 | 0.26                  | 0.66               | 0.98                 | 0.87               | 0.65               | 1.08             | 1.32             |
| MgO                 | 0.70                 | 0.96                  | 1.13               | 1.30                 | 0.84               | 0.97               | 0.98             | 1.14             |
| Na2O                | 4.31                 | 3.88                  | 3.83               | 3.83                 | 3.40               | 3.34               | 3.31             | 3.23             |
| K2O                 | 4.12                 | 4.26                  | 4.42               | 3.85                 | 4.17               | 4.55               | 4.34             | 4.60             |
| TiO2                | 0.04                 | 0.06                  | 0.25               | 0.36                 | 0.25               | 0.31               | 0.32             | 0.44             |
| P2O5                | 0.27                 | 0.23                  | 0.27               | 0.23                 | 0.26               | 0.29               | 0.21             | 0.27             |
| MnO                 | 0.06                 | 0.06                  | 0.04               | 0.06                 | 0.06               | 0.04               | 0.07             | 0.07             |
| H2O                 | 0.40                 | 0.70                  | 0.70               | 1.00                 | 0.80               | 1.10               | 0.60             | 0.70             |
| Q                   | 33.26                | 34.77                 | 31.87              | 30.41                | 34.24              | 33.32              | 33.15            | 29.30            |
| OR                  | 24.27                | 25.10                 | 26.00              | 22.95                | 24.96              | 27.14              | 25.91            | 27.56            |
| AB                  | 36.31                | 32.70                 | 32.22              | 32.66                | 29.11              | 28.49              | 28.27            | 27.68            |
| AN                  | 0.00                 | 0.00                  | 1.50               | 3.38                 | 2.65               | 1.34               | 4.02             | 4.84             |
| C                   | 2.60                 | 3.09                  | 2.67               | 3.50                 | 3.83               | 3.84               | 2.75             | 3.24             |
| EN                  | 1.74                 | 2.38                  | 2.80               | 3.26                 | 2.12               | 2.44               | 2.46             | 2.88             |
| IL                  | 0.08                 | 0.11                  | 0.09               | 0.13                 | 0.13               | 0.09               | 0.15             | 0.15             |
| HM                  | 1.05                 | 1.29                  | 2.03               | 2.88                 | 2.18               | 2.41               | 2.55             | 3.35             |
| RU                  | 0.00                 | 0.00                  | 0.20               | 0.29                 | 0.18               | 0.27               | 0.24             | 0.37             |
| AP                  | 0.62                 | 0.53                  | 0.62               | 0.54                 | 0.61               | 0.68               | 0.49             | 0.63             |
| A/CNK               | 1.18                 | 1.23                  | 1.17               | 1.24                 | 1.27               | 1.27               | 1.18             | 1.20             |
| TTDI                | 93.84                | 92.57                 | 90.09              | 86.02                | 88.31              | 88.94              | 87.33            | 84.54            |
| Col Ind             | 2.94                 | 3.81                  | 4.91               | 6.27                 | 4.42               | 4.93               | 5.17             | 6.38             |
| Ba                  | 11                   | 29                    | 252                | 276                  | 217                | 289                | 320              | 393              |
| Rb                  | 509                  | 363                   | 251                | 283                  | 246                | 243                | 223              | 253              |
| Sr                  | 5                    | 10                    | 49                 | 106                  | 57                 | 72                 | 97               | 93               |
| Zr                  | 36                   | 43                    | 101                | 111                  | 84                 | 115                | 107              | 143              |
| Nb                  | 9                    | 10                    | 13                 | 11                   | 13                 | 15                 | 10               | 14               |
| V                   | 0                    | 1                     | 19                 | 26                   | 18                 | 16                 | 23               | 30               |
| Y                   | 20                   | 19                    | 20                 | 21                   | 17                 | 20                 | 23               | 26               |
| Ga                  | 24                   | 22                    | 19                 | 22                   | 21                 | 22                 | 25               | 20               |
| Cu                  | 7                    | 0                     | 0                  | 0                    | 0                  | 4                  | 0                | 0                |
| Zn                  | 51                   | 37                    | 23                 | 95                   | 52                 | 49                 | 52               | 58               |
| Hf                  | 1                    | 1                     | 3                  | 3                    | 2                  | 3                  | 3                | 5                |
| Ta                  | 4.0                  | 2.2                   | 1.7                | 2.0                  | 2.7                | 1.7                | 1.6              | 2.4              |
| Sc                  | 2.4                  | 2.4                   | 3.7                | 5.4                  | 4.6                | 4.9                | 5.3              | 8.0              |
| La                  | 0                    | 3                     | 14                 | 17                   | 15                 | 23                 | 21               | 31               |
| Th                  | 3.4                  | 3.5                   | 11.0               | 7.0                  | 6.9                | 11.0               | 10.0             | 13.0             |
| U                   | 20.0                 | 13.0                  | 3.3                | 7.2                  | 7.3                | 3.5                | 5.4              | 8.0              |
| Li                  | 236                  | 86                    | 55                 | 140                  | 69                 | 56                 | 97               | 78               |
| F                   | 1100                 | 495                   | 1325               | 1080                 | 850                | 760                | 550              | 850              |
| As                  | 6.5                  | 1.8                   | 1.9                | 9.4                  | 6.9                | 8.0                | 0.9              | 3.8              |
| Sn                  | 44                   | 18                    | 16                 | 29                   | 17                 | 15                 | 13               | 12               |
| W                   | 6                    | 4                     | 6                  | 4                    | 1                  | 3                  | 1                | 1                |

HP cont.

| SAMPLE<br>Rock Type | D05-3043-1<br>MBMG | D05-3052<br>MBMG | D05-3099<br>MBMG | D05-3105<br>MBMG | D12-0021-1<br>MBMG | D12-0021-2<br>MBMG | D12-0021-3<br>MBMG | D12-0022-2<br>MBMG |
|---------------------|--------------------|------------------|------------------|------------------|--------------------|--------------------|--------------------|--------------------|
| SIO2                | 69.95              | 68.74            | 71.01            | 70.37            | 71.11              | 71.44              | 72.34              | 70.77              |
| AL2O3               | 15.10              | 15.42            | 14.87            | 15.18            | 14.27              | 14.16              | 14.09              | 14.72              |
| FE2O3               | 2.96               | 3.50             | 2.72             | 2.51             | 3.18               | 3.13               | 2.81               | 3.18               |
| CAO                 | 1.54               | 1.73             | 1.16             | 0.91             | 1.16               | 1.17               | 1.11               | 1.16               |
| MGO                 | 1.41               | 1.50             | 1.19             | 1.24             | 1.47               | 1.01               | 0.99               | 1.08               |
| NA2O                | 3.62               | 3.46             | 3.66             | 3.11             | 3.85               | 3.30               | 3.10               | 3.21               |
| K2O                 | 4.13               | 4.31             | 4.67             | 5.17             | 4.12               | 4.18               | 4.24               | 4.43               |
| TIO2                | 0.40               | 0.49             | 0.37             | 0.32             | 0.45               | 0.42               | 0.36               | 0.45               |
| P2O5                | 0.20               | 0.17             | 0.25             | 0.25             | 0.26               | 0.25               | 0.27               | 0.28               |
| MNO                 | 0.07               | 0.07             | 0.06             | 0.05             | 0.06               | 0.06               | 0.06               | 0.06               |
| H2O                 | 0.70               | 0.40             | 0.40             | 0.70             | 0.50               | 0.70               | 0.60               | 0.80               |
| Q                   | 28.41              | 26.80            | 28.29            | 29.65            | 29.01              | 33.22              | 35.20              | 32.03              |
| OR                  | 24.58              | 25.65            | 27.63            | 30.86            | 24.39              | 24.94              | 25.24              | 26.38              |
| AB                  | 30.82              | 29.45            | 30.98            | 26.55            | 32.60              | 28.17              | 26.39              | 27.34              |
| AN                  | 6.37               | 7.52             | 4.12             | 2.90             | 4.06               | 4.20               | 3.76               | 3.95               |
| C                   | 2.37               | 2.34             | 2.28             | 3.44             | 1.99               | 2.70               | 3.05               | 3.22               |
| EN                  | 3.53               | 3.76             | 2.96             | 3.12             | 3.66               | 2.54               | 2.48               | 2.71               |
| IL                  | 0.15               | 0.15             | 0.13             | 0.11             | 0.13               | 0.13               | 0.13               | 0.13               |
| HM                  | 2.98               | 3.52             | 2.72             | 2.53             | 3.18               | 3.16               | 2.83               | 3.20               |
| RU                  | 0.32               | 0.41             | 0.30             | 0.27             | 0.38               | 0.36               | 0.29               | 0.38               |
| AP                  | 0.47               | 0.40             | 0.58             | 0.59             | 0.60               | 0.59               | 0.63               | 0.65               |
| A/CNK               | 1.14               | 1.14             | 1.13             | 1.23             | 1.11               | 1.17               | 1.20               | 1.21               |
| TTDI                | 83.81              | 81.91            | 86.90            | 87.05            | 85.99              | 86.33              | 86.83              | 85.75              |
| Col. Ind.           | 6.66               | 7.43             | 5.81             | 5.76             | 6.97               | 5.82               | 5.44               | 6.04               |
| Ba                  | 472                | 552              | 415              | 501              | 325                | 304                | 303                | 363                |
| Rb                  | 194                | 178              | 245              | 258              | 236                | 235                | 226                | 238                |
| Sr                  | 132                | 161              | 89               | 99               | 89                 | 91                 | 79                 | 92                 |
| Zr                  | 147                | 161              | 123              | 116              | 152                | 139                | 123                | 140                |
| Nb                  | 13                 | 11               | 14               | 13               | 16                 | 13                 | 13                 | 16                 |
| V                   | 28                 | 38               | 23               | 18               | 36                 | 30                 | 20                 | 28                 |
| Y                   | 27                 | 30               | 22               | 22               | 28                 | 25                 | 24                 | 24                 |
| Ga                  | 24                 | 26               | 22               | 26               | 22                 | 20                 | 17                 | 18                 |
| Cu                  | 0                  | 6                | 0                | 0                | 0                  | 0                  | 55                 | 3                  |
| Zn                  | 62                 | 57               | 56               | 58               | 84                 | 54                 | 17                 | 60                 |
| Hf                  | 4                  | 5                | 4                | 4                | 6                  | 3                  | 3                  | 4                  |
| Ta                  | 1.0                | 1.0              | 1.6              | 1.4              | 1.9                | 0.7                | 1.4                | 1.6                |
| Sc                  | 6.8                | 8.6              | 5.8              | 4.8              | 7.2                | 4.9                | 5.2                | 5.9                |
| La                  | 28                 | 32               | 23               | 22               | 30                 | 17                 | 22                 | 26                 |
| Th                  | 13.0               | 12.0             | 11.0             | 11.0             | 13.0               | 5.7                | 10.0               | 12.0               |
| U                   | 5.9                | 3.1              | 4.1              | 4.0              | 8.5                | 1.9                | 5.6                | 2.7                |
| Li                  | 91                 | 82               | 97               | 89               | 113                | 110                | 122                | 126                |
| F                   | 730                | 730              | 925              | 690              | 790                | 800                | 740                | 710                |
| As                  | 2.6                | 1.1              | 2.6              | 1.0              | 2.0                | 2.0                | 3.3                | 1.0                |
| Sn                  | 7                  | 5                | 9                | 4                | 9                  | 3                  | 11                 | 9                  |
| W                   | 1                  | 1                | 1                | 1                | 1                  | 1                  | 1                  | 1                  |

HP cont.

| SAMPLE<br>Rock Type | D12-0023-1<br>MBMG | D12-0033<br>MBMG | D12-0033-3<br>MBMG | D12-0035<br>MBMG | D12-0037<br>MBMG | D12-0039<br>MBMG | D12-0040-1<br>MBMG | D12-0042<br>MBMG |
|---------------------|--------------------|------------------|--------------------|------------------|------------------|------------------|--------------------|------------------|
| SiO2                | 70.05              | 70.40            | 71.06              | 70.78            | 71.72            | 71.39            | 71.98              | 71.77            |
| Al2O3               | 14.96              | 14.83            | 14.37              | 14.80            | 14.46            | 14.57            | 14.64              | 14.28            |
| Fe2O3               | 2.94               | 3.22             | 3.19               | 2.65             | 2.61             | 2.57             | 2.25               | 2.33             |
| CaO                 | 1.13               | 1.05             | 0.66               | 0.86             | 1.03             | 0.90             | 0.70               | 0.52             |
| MgO                 | 1.36               | 1.08             | 1.52               | 1.19             | 1.26             | 1.26             | 1.30               | 1.37             |
| Na2O                | 3.41               | 3.36             | 3.61               | 3.82             | 3.96             | 3.53             | 3.84               | 3.85             |
| K2O                 | 4.64               | 4.41             | 4.19               | 4.83             | 4.31             | 4.58             | 4.79               | 4.62             |
| TiO2                | 0.44               | 0.46             | 0.42               | 0.38             | 0.37             | 0.37             | 0.31               | 0.35             |
| P2O5                | 0.26               | 0.26             | 0.23               | 0.26             | 0.22             | 0.26             | 0.28               | 0.27             |
| MnO                 | 0.06               | 0.08             | 0.07               | 0.06             | 0.06             | 0.05             | 0.05               | 0.04             |
| H2O                 | 0.60               | 0.90             | 1.00               | 0.60             | 0.40             | 0.60             | 0.60               | 0.80             |
| Q                   | 28.94              | 31.10            | 31.19              | 27.28            | 28.71            | 30.40            | 28.61              | 29.46            |
| OR                  | 27.65              | 26.31            | 24.95              | 28.68            | 25.49            | 27.23            | 28.29              | 27.49            |
| AB                  | 29.07              | 28.67            | 30.75              | 32.44            | 33.50            | 30.02            | 32.44              | 32.77            |
| AN                  | 3.93               | 3.54             | 1.78               | 2.57             | 3.67             | 2.78             | 1.64               | 0.82             |
| C                   | 2.91               | 3.27             | 3.27               | 2.35             | 1.93             | 2.80             | 2.53               | 2.66             |
| EN                  | 3.41               | 2.71             | 3.81               | 2.97             | 3.14             | 3.15             | 3.23               | 3.43             |
| IL                  | 0.13               | 0.17             | 0.15               | 0.13             | 0.13             | 0.11             | 0.11               | 0.09             |
| HM                  | 2.96               | 3.25             | 3.21               | 2.66             | 2.61             | 2.58             | 2.25               | 2.34             |
| RU                  | 0.38               | 0.37             | 0.34               | 0.31             | 0.30             | 0.32             | 0.25               | 0.31             |
| AP                  | 0.61               | 0.61             | 0.54               | 0.61             | 0.51             | 0.61             | 0.65               | 0.63             |
| A/CNK               | 1.18               | 1.21             | 1.23               | 1.13             | 1.11             | 1.17             | 1.15               | 1.16             |
| TTDI                | 85.66              | 86.08            | 86.90              | 88.39            | 87.71            | 87.65            | 89.34              | 89.72            |
| Col. Ind.           | 6.50               | 6.13             | 7.17               | 5.76             | 5.88             | 5.85             | 5.59               | 5.86             |
| Ba                  | 466                | 390              | 247                | 366              | 264              | 369              | 305                | 369              |
| Rb                  | 249                | 237              | 235                | 278              | 240              | 246              | 275                | 270              |
| Sr                  | 106                | 106              | 80                 | 89               | 80               | 89               | 70                 | 75               |
| Zr                  | 139                | 141              | 135                | 122              | 119              | 133              | 124                | 131              |
| Nb                  | 14                 | 14               | 15                 | 15               | 14               | 13               | 14                 | 14               |
| V                   | 32                 | 35               | 32                 | 27               | 23               | 22               | 20                 | 15               |
| Y                   | 24                 | 24               | 27                 | 23               | 24               | 23               | 23                 | 24               |
| Ga                  | 23                 | 20               | 24                 | 22               | 20               | 24               | 23                 | 23               |
| Cu                  | 10                 | 0                | 0                  | 0                | 0                | 0                | 3                  | 0                |
| Zn                  | 57                 | 85               | 234                | 60               | 55               | 60               | 50                 | 57               |
| Hf                  | 4                  | 5                | 4                  | 4                | 4                | 3                | 3                  | 3                |
| Ta                  | 1.7                | 1.8              | 1.5                | 1.9              | 1.8              | 1.4              | 1.8                | 2.0              |
| Sc                  | 5.7                | 6.2              | 6.3                | 5.6              | 5.5              | 5.2              | 4.9                | 4.8              |
| La                  | 24                 | 25               | 23                 | 23               | 22               | 23               | 22                 | 25               |
| Th                  | 11.0               | 11.0             | 10.0               | 11.0             | 11.0             | 13.0             | 12.0               | 14.0             |
| U                   | 3.9                | 3.0              | 4.1                | 2.4              | 3.4              | 5.9              | 5.2                | 4.1              |
| Li                  | 90                 | 89               | 63                 | 96               | 95               | 94               | 83                 | 90               |
| F                   | 770                | 740              | 540                | 780              | 650              | 690              | 700                | 575              |
| As                  | 1.7                | 3.1              | 3.1                | 1.6              | 1.4              | 3.7              | 3.8                | 18.0             |
| Sn                  | 7                  | 12               | 12                 | 8                | 6                | 10               | 10                 | 13               |
| W                   | 1                  | 1                | 5                  | 1                | 1                | 2                | 2                  | 2                |



# HP cont.

| SAMPLE<br>Rock Type | D12-0045-C<br>MBMG | D12-0058-1<br>MBMG | D12-3015<br>MBMG | D12-3036<br>MBMG | D12-3036-5<br>MBMG | D12-3037-C<br>MBMG | D12-3072<br>MBMG | D05-3059<br>MP |
|---------------------|--------------------|--------------------|------------------|------------------|--------------------|--------------------|------------------|----------------|
| SiO2                | 71.83              | 70.80              | 71.57            | 73.88            | 70.60              | 71.39              | 70.80            | 70.13          |
| Al2O3               | 14.76              | 14.66              | 14.32            | 13.99            | 14.75              | 14.21              | 14.87            | 14.65          |
| Fe2O3               | 2.12               | 3.07               | 3.26             | 1.87             | 3.20               | 3.10               | 2.62             | 2.50           |
| CaO                 | 0.71               | 1.17               | 1.10             | 0.45             | 1.23               | 1.11               | 0.74             | 1.21           |
| MgO                 | 1.12               | 1.31               | 1.13             | 0.85             | 1.14               | 1.52               | 1.40             | 3.60           |
| Na2O                | 4.89               | 3.49               | 3.11             | 3.40             | 2.99               | 3.49               | 4.34             | 3.63           |
| K2O                 | 4.49               | 4.45               | 4.27             | 4.54             | 4.61               | 4.22               | 4.67             | 4.14           |
| TiO2                | 0.27               | 0.46               | 0.46             | 0.21             | 0.45               | 0.46               | 0.38             | 0.29           |
| P2O5                | 0.30               | 0.27               | 0.25             | 0.25             | 0.26               | 0.26               | 0.28             | 0.20           |
| MNO                 | 0.06               | 0.06               | 0.06             | 0.05             | 0.07               | 0.07               | 0.05             | 0.07           |
| H2O                 | 0.60               | 0.50               | 0.60             | 0.80             | 0.70               | 0.80               | 0.60             | 0.50           |
| Q                   | 23.71              | 29.83              | 33.95            | 35.37            | 32.17              | 31.07              | 24.75            | 25.65          |
| OR                  | 26.41              | 26.39              | 25.38            | 26.99            | 27.46              | 25.00              | 27.58            | 24.39          |
| AB                  | 41.15              | 29.60              | 26.44            | 28.91            | 25.48              | 29.58              | 36.66            | 30.58          |
| AN                  | 1.55               | 4.05               | 3.84             | 0.60             | 4.43               | 3.81               | 1.84             | 4.67           |
| C                   | 1.27               | 2.63               | 3.19             | 3.28             | 3.25               | 2.51               | 1.99             | 2.46           |
| EN                  | 2.77               | 3.27               | 2.83             | 2.13             | 2.86               | 3.79               | 3.48             | 8.93           |
| IL                  | 0.13               | 0.13               | 0.13             | 0.11             | 0.15               | 0.15               | 0.11             | 0.15           |
| HM                  | 2.11               | 3.08               | 3.28             | 1.88             | 3.22               | 3.11               | 2.62             | 2.49           |
| RU                  | 0.20               | 0.39               | 0.39             | 0.15             | 0.37               | 0.38               | 0.32             | 0.21           |
| AP                  | 0.69               | 0.63               | 0.58             | 0.58             | 0.61               | 0.60               | 0.65             | 0.46           |
| A/CNK               | 1.04               | 1.16               | 1.22             | 1.24             | 1.21               | 1.15               | 1.10             | 1.16           |
| TTDI                | 91.27              | 85.83              | 85.76            | 91.27            | 85.11              | 85.65              | 88.99            | 80.62          |
| Col. Ind.           | 5.01               | 6.48               | 6.23             | 4.11             | 6.23               | 7.05               | 6.20             | 11.57          |
| Ba                  | 279                | 399                | 378              | 105              | 442                | 308                | 363              | 262            |
| Rb                  | 264                | 253                | 219              | 278              | 220                | 230                | 269              | 220            |
| Sr                  | 65                 | 94                 | 100              | 33               | 100                | 92                 | 92               | 89             |
| Zr                  | 107                | 141                | 138              | 83               | 140                | 147                | 137              | 90             |
| Nb                  | 14                 | 14                 | 14               | 13               | 14                 | 14                 | 16               | 10             |
| V                   | 13                 | 33                 | 35               | 12               | 29                 | 31                 | 21               | 20             |
| Y                   | 20                 | 25                 | 25               | 20               | 25                 | 26                 | 24               | 22             |
| Ga                  | 24                 | 21                 | 20               | 22               | 19                 | 23                 | 23               | 19             |
| Cu                  | 0                  | 0                  | 1                | 1                | 0                  | 0                  | 0                | 0              |
| Zn                  | 55                 | 61                 | 56               | 44               | 61                 | 58                 | 63               | 43             |
| Hf                  | 3                  | 4                  | 5                | 2                | 4                  | 4                  | 3                | 3              |
| Ta                  | 1.9                | 1.6                | 1.4              | 2.4              | 1.7                | 2.0                | 2.0              | 1.1            |
| Sc                  | 4.2                | 6.2                | 6.7              | 3.7              | 5.7                | 6.1                | 5.4              | 8.8            |
| La                  | 17                 | 26                 | 28               | 15               | 25                 | 26                 | 25               | 27             |
| Th                  | 9.3                | 12.0               | 12.0             | 7.8              | 11.0               | 12.0               | 13.0             | 12.0           |
| U                   | 4.9                | 2.6                | 5.0              | 3.8              | 4.2                | 3.5                | 3.5              | 3.6            |
| Li                  | 95                 | 94                 | 87               | 88               | 73                 | 97                 | 84               | 95             |
| F                   | 770                | 730                | 660              | 450              | 640                | 770                | 765              | 710            |
| As                  | 5.1                | 0.8                | 1.6              | 2.7              | 2.1                | 2.7                | 1.6              | 6.1            |
| Sn                  | 12                 | 6                  | 9                | 15               | 10                 | 13                 | 10               | 15             |
| W                   | 2                  | 1                  | 1                | 2                | 1                  | 1                  | 3                | 1              |

# HP cont.

| SAMPLE<br>Rock Type | D05-3060<br>MP | D05-0016-1<br>BMGp | D05-0016-2<br>BMGp | D05-0018<br>BMGp | D05-3098-3<br>BMGp | D12-0048-3<br>BMGp | D12-0049<br>BMGp | D12-3084-2<br>BMGp |
|---------------------|----------------|--------------------|--------------------|------------------|--------------------|--------------------|------------------|--------------------|
| SiO2                | 67.94          | 72.57              | 70.66              | 69.50            | 69.75              | 70.83              | 69.30            | 71.40              |
| Al2O3               | 14.84          | 14.03              | 14.63              | 14.96            | 14.93              | 14.64              | 15.88            | 14.24              |
| Fe2O3               | 3.98           | 2.53               | 2.97               | 3.18             | 3.48               | 2.89               | 2.66             | 2.95               |
| CaO                 | 2.32           | 1.06               | 1.37               | 1.44             | 1.40               | 1.32               | 1.25             | 0.92               |
| MgO                 | 2.12           | 1.25               | 1.52               | 1.25             | 1.32               | 1.31               | 1.04             | 2.30               |
| Na2O                | 4.56           | 3.59               | 3.56               | 3.13             | 3.13               | 3.64               | 3.50             | 4.05               |
| K2O                 | 3.49           | 4.57               | 4.18               | 4.64             | 4.22               | 4.61               | 5.20             | 4.52               |
| TiO2                | 0.56           | 0.31               | 0.41               | 0.44             | 0.46               | 0.36               | 0.33             | 0.38               |
| P2O5                | 0.20           | 0.17               | 0.19               | 0.18             | 0.19               | 0.14               | 0.16             | 0.16               |
| MnO                 | 0.08           | 0.06               | 0.06               | 0.07             | 0.08               | 0.06               | 0.07             | 0.07               |
| H2O                 | 0.70           | 0.40               | 0.40               | 0.60             | 0.90               | 0.60               | 0.60             | 0.30               |
| Q                   | 20.57          | 30.48              | 29.41              | 29.43            | 31.27              | 27.68              | 25.40            | 25.33              |
| OR                  | 20.62          | 26.99              | 24.84              | 27.78            | 25.22              | 27.32              | 30.95            | 26.47              |
| AB                  | 38.55          | 30.33              | 30.26              | 26.81            | 26.76              | 30.85              | 29.79            | 33.93              |
| AN                  | 9.70           | 4.14               | 5.58               | 6.04             | 5.76               | 5.64               | 5.19             | 3.48               |
| C                   | 0.00           | 1.65               | 2.22               | 2.63             | 3.15               | 1.60               | 2.62             | 1.38               |
| EN                  | 5.10           | 3.11               | 3.80               | 3.15             | 3.32               | 3.27               | 2.61             | 5.67               |
| IL                  | 0.17           | 0.13               | 0.13               | 0.15             | 0.17               | 0.13               | 0.15             | 0.15               |
| HM                  | 3.98           | 2.53               | 2.98               | 3.22             | 3.52               | 2.90               | 2.68             | 2.92               |
| RU                  | 0.47           | 0.24               | 0.34               | 0.37             | 0.37               | 0.31               | 0.25             | 0.30               |
| AP                  | 0.46           | 0.39               | 0.44               | 0.42             | 0.45               | 0.33               | 0.37             | 0.37               |
| A/CNK               | 0.96           | 1.10               | 1.14               | 1.17             | 1.22               | 1.09               | 1.16             | 1.08               |
| TTDI                | 79.74          | 87.81              | 84.50              | 84.02            | 83.26              | 85.83              | 86.14            | 85.73              |
| Col. Ind            | 9.63           | 5.76               | 6.91               | 6.52             | 7.01               | 6.29               | 5.43             | 8.74               |
| Ba                  | 446            | 327                | 412                | 640              | 484                | 477                | 470              | 441                |
| Rb                  | 182            | 192                | 190                | 176              | 184                | 178                | 199              | 197                |
| Sr                  | 151            | 88                 | 122                | 151              | 125                | 124                | 124              | 130                |
| Zr                  | 148            | 118                | 135                | 142              | 153                | 137                | 110              | 136                |
| Nb                  | 12             | 10                 | 10                 | 11               | 11                 | 10                 | 10               | 12                 |
| V                   | 50             | 22                 | 29                 | 31               | 33                 | 27                 | 23               | 25                 |
| Y                   | 22             | 28                 | 24                 | 27               | 30                 | 34                 | 28               | 29                 |
| Ga                  | 20             | 19                 | 21                 | 18               | 19                 | 24                 | 20               | 24                 |
| Cu                  | 4              | 0                  | 0                  | 5                | 2                  | 0                  | 0                | 0                  |
| Zn                  | 74             | 53                 | 53                 | 54               | 64                 | 53                 | 48               | 73                 |
| Hf                  | 3              | 4                  | 5                  | 4                | 5                  | 5                  | 3                | 5                  |
| Ta                  | 1.6            | 1.2                | 1.3                | 1.1              | 1.2                | 1.0                | 1.2              | 1.1                |
| Sc                  | 5.5            | 5.2                | 6.8                | 7.2              | 7.7                | 6.6                | 5.3              | 5.4                |
| La                  | 16             | 21                 | 27                 | 30               | 31                 | 24                 | 23               | 22                 |
| Th                  | 8.0            | 11.0               | 13.0               | 12.0             | 12.0               | 11.0               | 10.0             | 12.0               |
| U                   | 4.4            | 4.2                | 3.1                | 2.2              | 2.9                | 3.4                | 3.0              | 6.9                |
| Li                  | 94             | 79                 | 81                 | 65               | 88                 | 75                 | 84               | 80                 |
| F                   | 590            | 580                | 590                | 550              | 730                | 520                | 550              | 500                |
| As                  | 2.4            | 1.8                | 1.8                | 3.3              | 1.0                | 1.2                | 2.0              | 6.1                |
| Sn                  | 12             | 8                  | 9                  | 8                | 1                  | 5                  | 8                | 4                  |
| W                   | 1              | 1                  | 1                  | 1                | 1                  | 1                  | 1                | 1                  |

# HP cont.

| SAMPLE<br>Rock Type | D12-3088<br>BMGp | D12-3097<br>BMGp | D12-0028<br>BMGs | D12-0085-2<br>BMGs | D12-0095<br>BMGs | D12-0098<br>BMGs | D12-0099<br>BMGs | D12-0104<br>BMGs |
|---------------------|------------------|------------------|------------------|--------------------|------------------|------------------|------------------|------------------|
| SIO2                | 70.10            | 69.31            | 69.28            | 70.19              | 68.71            | 70.13            | 67.29            | 71.99            |
| AL2O3               | 14.95            | 15.46            | 15.10            | 14.99              | 15.43            | 15.12            | 15.43            | 14.74            |
| FE2O3               | 2.97             | 2.78             | 3.71             | 2.92               | 3.78             | 3.26             | 4.67             | 2.42             |
| CAO                 | 1.14             | 1.13             | 1.68             | 1.18               | 1.08             | 0.96             | 1.72             | 0.79             |
| MGO                 | 1.09             | 1.38             | 1.34             | 1.17               | 1.68             | 1.34             | 1.63             | 1.16             |
| NA2O                | 3.17             | 3.41             | 3.40             | 3.41               | 3.55             | 3.41             | 3.49             | 3.40             |
| K2O                 | 4.75             | 5.16             | 4.13             | 4.64               | 4.45             | 4.52             | 3.86             | 5.07             |
| TIO2                | 0.36             | 0.36             | 0.51             | 0.38               | 0.53             | 0.42             | 0.66             | 0.27             |
| P2O5                | 0.14             | 0.17             | 0.18             | 0.19               | 0.20             | 0.19             | 0.21             | 0.15             |
| MNO                 | 0.08             | 0.06             | 0.07             | 0.07               | 0.08             | 0.09             | 0.10             | 0.06             |
| H2O                 | 0.60             | 0.60             | 0.60             | 0.50               | 0.80             | 0.70             | 0.80             | 0.50             |
| Q                   | 30.17            | 25.91            | 28.77            | 29.09              | 26.90            | 29.63            | 26.93            | 29.78            |
| OR                  | 28.45            | 30.76            | 24.58            | 27.68              | 26.46            | 26.89            | 23.05            | 29.97            |
| AB                  | 27.16            | 29.08            | 28.94            | 29.10              | 30.19            | 29.01            | 29.81            | 28.75            |
| AN                  | 4.80             | 4.53             | 7.20             | 4.65               | 4.07             | 3.54             | 7.23             | 2.94             |
| C                   | 2.89             | 2.63             | 2.42             | 2.69               | 3.30             | 3.34             | 2.91             | 2.58             |
| EN                  | 2.75             | 3.46             | 3.36             | 2.94               | 4.21             | 3.36             | 4.10             | 2.89             |
| IL                  | 0.17             | 0.13             | 0.15             | 0.15               | 0.17             | 0.19             | 0.22             | 0.13             |
| HM                  | 3.01             | 2.80             | 3.73             | 2.95               | 3.80             | 3.28             | 4.71             | 2.42             |
| RU                  | 0.27             | 0.29             | 0.43             | 0.30               | 0.44             | 0.32             | 0.55             | 0.20             |
| AP                  | 0.33             | 0.40             | 0.42             | 0.44               | 0.47             | 0.44             | 0.49             | 0.35             |
| A/CNK               | 1.20             | 1.17             | 1.15             | 1.17               | 1.22             | 1.23             | 1.18             | 1.18             |
| TTDI                | 85.78            | 85.75            | 82.28            | 85.88              | 83.54            | 85.53            | 79.79            | 88.50            |
| Col. Ind.           | 5.93             | 6.39             | 7.24             | 6.04               | 8.18             | 6.83             | 9.03             | 5.43             |
| Ba                  | 428              | 503              | 584              | 446                | 725              | 500              | 614              | 304              |
| Rb                  | 207              | 215              | 173              | 201                | 249              | 222              | 165              | 242              |
| Sr                  | 109              | 127              | 145              | 112                | 150              | 129              | 182              | 67               |
| Zr                  | 132              | 129              | 166              | 123                | 173              | 149              | 194              | 107              |
| Nb                  | 11               | 10               | 12               | 11                 | 13               | 11               | 13               | 12               |
| V                   | 23               | 24               | 33               | 23                 | 40               | 29               | 49               | 17               |
| Y                   | 31               | 28               | 31               | 28                 | 33               | 32               | 32               | 29               |
| Ga                  | 21               | 26               | 22               | 18                 | 21               | 17               | 20               | 24               |
| Cu                  | 0                | 0                | 3                | 4                  | 8                | 14               | 6                | 0                |
| Zn                  | 65               | 138              | 59               | 57                 | 100              | 75               | 71               | 51               |
| Hf                  | 4                | 4                | 4                | 3                  | 5                | 4                | 6                | 4                |
| Ta                  | 1.1              | 0.9              | 1.1              | 1.4                | 1.1              | 1.1              | 1.2              | 1.3              |
| Sc                  | 6.7              | 5.6              | 7.7              | 6.8                | 8.2              | 6.9              | 10.0             | 4.9              |
| La                  | 27               | 24               | 31               | 26                 | 34               | 27               | 37               | 19               |
| Th                  | 12.0             | 11.0             | 12.0             | 11.0               | 12.0             | 11.0             | 12.0             | 10.0             |
| U                   | 4.4              | 2.7              | 3.4              | 4.8                | 3.0              | 2.8              | 2.8              | 3.8              |
| Li                  | 72               | 90               | 96               | 90                 | 106              | 128              | 102              | 82               |
| F                   | 590              | 580              | 610              | 680                | 860              | 830              | 710              | 590              |
| As                  | 3.2              | 3.5              | 1.8              | 1.4                | 1.4              | 2.1              | 3.8              | 1.5              |
| Sn                  | 15               | 3                | 5                | 12                 | 9                | 10               | 5                | 10               |
| W                   | 1                | 1                | 1                | 2                  | 3                | 1                | 2                | 1                |

# HP cont.

| SAMPLE<br>Rock Type | D12-0106<br>BMGs | D12-0122-C<br>BMGs | D12-0142<br>BMGs |
|---------------------|------------------|--------------------|------------------|
| SiO2                | 69.63            | 72.85              | 70.77            |
| Al2O3               | 14.92            | 13.84              | 14.54            |
| Fe2O3               | 3.42             | 2.83               | 3.00             |
| CaO                 | 1.47             | 0.85               | 0.79             |
| MgO                 | 1.19             | 1.56               | 1.52             |
| Na2O                | 3.04             | 3.52               | 3.58             |
| K2O                 | 4.33             | 4.01               | 4.30             |
| TiO2                | 0.45             | 0.35               | 0.37             |
| P2O5                | 0.18             | 0.17               | 0.18             |
| MnO                 | 0.07             | 0.07               | 0.07             |
| H2O                 | 0.50             | 0.70               | 1.00             |
| Q                   | 31.35            | 33.33              | 30.29            |
| OR                  | 25.95            | 23.71              | 25.66            |
| AB                  | 26.06            | 29.77              | 30.56            |
| AN                  | 6.20             | 3.10               | 2.77             |
| C                   | 3.03             | 2.57               | 3.01             |
| EN                  | 3.00             | 3.88               | 3.82             |
| IL                  | 0.15             | 0.15               | 0.15             |
| HM                  | 3.47             | 2.83               | 3.03             |
| RU                  | 0.38             | 0.27               | 0.29             |
| AP                  | 0.42             | 0.39               | 0.42             |
| A/CNK               | 1.21             | 1.19               | 1.21             |
| TTDI                | 83.36            | 86.80              | 86.51            |
| Col Ind             | 6.62             | 6.86               | 7.00             |
| Ba                  | 474              | 295                | 325              |
| Rb                  | 177              | 198                | 204              |
| Sr                  | 126              | 85                 | 99               |
| Zr                  | 148              | 134                | 139              |
| Nb                  | 10               | 11                 | 12               |
| V                   | 33               | 26                 | 30               |
| Y                   | 31               | 29                 | 30               |
| Ga                  | 21               | 21                 | 25               |
| Cu                  | 0                | 0                  | 0                |
| Zn                  | 59               | 52                 | 69               |
| Hf                  | 4                | 4                  | 5                |
| Ta                  | 1.1              | 1.2                | 1.5              |
| Sc                  | 7.2              | 5.5                | 6.8              |
| La                  | 30               | 23                 | 24               |
| Th                  | 12.0             | 12.0               | 12.0             |
| U                   | 2.6              | 5.4                | 2.5              |
| Li                  | 96               | 108                | 60               |
| F                   | 680              | 550                | 780              |
| As                  | 1.5              | 1.8                | 1.3              |
| Sn                  | 9                | 6                  | 2                |
| W                   | 1                | 1                  | 1                |

# KEJIMKUJIK PLUTON (KP)

| SAMPLE                         | A06-3007 | A06-3010-1 | A06-3021 |
|--------------------------------|----------|------------|----------|
| Rock Type                      | MBMG     | MBMG       | MBMG     |
| Major Elements (wt %)          |          |            |          |
| SiO <sub>2</sub>               | 69.56    | 69.54      | 70.59    |
| Al <sub>2</sub> O <sub>3</sub> | 15.22    | 15.17      | 15.07    |
| Fe <sub>2</sub> O <sub>3</sub> | 3.74     | 3.34       | 3.35     |
| CaO                            | 1.12     | 1.04       | 0.67     |
| MgO                            | 1.55     | 1.46       | 1.45     |
| Na <sub>2</sub> O              | 2.95     | 3.27       | 3.05     |
| K <sub>2</sub> O               | 4.08     | 4.49       | 4.29     |
| TiO <sub>2</sub>               | 0.48     | 0.46       | 0.44     |
| P <sub>2</sub> O <sub>5</sub>  | 0.24     | 0.23       | 0.24     |
| MnO                            | 0.10     | 0.09       | 0.09     |
| H <sub>2</sub> O               | 0.80     | 0.60       | 1.10     |
| Normative Mineralogy           |          |            |          |
| Q                              | 33.06    | 29.84      | 33.75    |
| OR                             | 24.37    | 26.80      | 25.57    |
| AB                             | 25.20    | 27.92      | 26.00    |
| AN                             | 4.02     | 3.69       | 1.77     |
| C                              | 4.53     | 3.62       | 4.80     |
| EN                             | 3.90     | 3.67       | 3.64     |
| IL                             | 0.22     | 0.19       | 0.19     |
| HM                             | 3.78     | 3.37       | 3.38     |
| RU                             | 0.37     | 0.36       | 0.34     |
| AP                             | 0.56     | 0.54       | 0.56     |
| A/CNK                          | 1.35     | 1.25       | 1.39     |
| TTDI                           | 82.62    | 84.56      | 85.32    |
| Col. Ind.                      | 7.89     | 7.23       | 7.21     |
| Trace Elements (ppm)           |          |            |          |
| Ba                             | 509      | 629        | 531      |
| Rb                             | 191      | 192        | 204      |
| Sr                             | 109      | 118        | 96       |
| Zr                             | 159      | 147        | 139      |
| Nb                             | 10       | 10         | 10       |
| V                              | 43       | 41         | 39       |
| Y                              | 28       | 28         | 26       |
| Ga                             | 18       | 16         | 18       |
| Cu                             | 0        | 0          | 0        |
| Zn                             | 69       | 58         | 48       |
| Hf                             | 4        | 4          | 4        |
| Ta                             | 1.4      | 1.4        | 2.2      |
| Sc                             | 6.5      | 6.4        | 6.0      |
| La                             | 28       | 28         | 26       |
| Th                             | 11.0     | 11.0       | 11.0     |
| U                              | 2.7      | 4.3        | 7.4      |
| Li                             | 77       | 69         | 81       |
| F                              | 622      | 485        | 494      |
| As                             | 0.9      | 1.2        | 2.7      |
| Sn                             | 0        | 3          | 6        |
| W                              | 0        | 0          | 3        |

# MORSE ROAD PLUTON (MRP)

| SAMPLE                         | A14-1018 | A14-1018-1 | A14-1019 | A14-1020 | A14-1020-1 |
|--------------------------------|----------|------------|----------|----------|------------|
| Rock Type                      | CGLMG    | CGLMG      | CGLMG    | MBMG     | MBMG       |
| Major Elements (wt %)          |          |            |          |          |            |
| SiO <sub>2</sub>               | 72.11    | 71.62      | 72.12    | 73.04    | 72.83      |
| Al <sub>2</sub> O <sub>3</sub> | 14.99    | 15.50      | 14.76    | 14.27    | 14.52      |
| Fe <sub>2</sub> O <sub>3</sub> | 1.87     | 1.92       | 2.22     | 1.75     | 2.04       |
| CaO                            | 0.63     | 0.68       | 0.68     | 0.60     | 0.80       |
| MgO                            | 1.02     | 1.12       | 1.12     | 1.08     | 1.37       |
| Na <sub>2</sub> O              | 3.29     | 2.98       | 3.17     | 3.35     | 3.14       |
| K <sub>2</sub> O               | 5.23     | 5.56       | 4.86     | 5.04     | 4.89       |
| TiO <sub>2</sub>               | 0.23     | 0.27       | 0.33     | 0.24     | 0.26       |
| P <sub>2</sub> O <sub>5</sub>  | 0.20     | 0.21       | 0.22     | 0.19     | 0.15       |
| MnO                            | 0.04     | 0.04       | 0.05     | 0.04     | 0.05       |
| H <sub>2</sub> O               | 0.60     | 0.50       | 0.60     | 0.50     | 0.60       |
| Normative Mineralogy           |          |            |          |          |            |
| Q                              | 30.75    | 30.48      | 32.71    | 32.02    | 32.48      |
| OR                             | 31.06    | 32.92      | 28.88    | 29.93    | 28.91      |
| AB                             | 27.94    | 25.24      | 26.95    | 28.46    | 26.55      |
| AN                             | 1.82     | 2.00       | 1.94     | 1.74     | 2.99       |
| C                              | 3.26     | 3.85       | 3.59     | 2.67     | 2.96       |
| EN                             | 2.55     | 2.79       | 2.80     | 2.70     | 3.41       |
| IL                             | 0.09     | 0.09       | 0.11     | 0.09     | 0.11       |
| HM                             | 1.88     | 1.92       | 2.23     | 1.76     | 2.04       |
| RU                             | 0.19     | 0.23       | 0.27     | 0.20     | 0.20       |
| AP                             | 0.47     | 0.49       | 0.51     | 0.44     | 0.35       |
| A/CNK                          | 1.23     | 1.28       | 1.26     | 1.18     | 1.22       |
| TTDI                           | 89.75    | 88.64      | 88.54    | 90.40    | 87.95      |
| Col. Ind.                      | 4.51     | 4.80       | 5.14     | 4.54     | 5.56       |
| Trace Elements (ppm*)          |          |            |          |          |            |
| Ba                             | 368      | 445        | 361      | 400      | 351        |
| Rb                             | 279      | 262        | 262      | 230      | 204        |
| Sr                             | 74       | 88         | 75       | 82       | 78         |
| Zr                             | 99       | 114        | 138      | 107      | 103        |
| Nb                             | 14       | 12         | 15       | 12       | 10         |
| V                              | 8        | 12         | 12       | 12       | 18         |
| Y                              | 22       | 23         | 24       | 23       | 24         |
| Ga                             | 19       | 18         | 19       | 15       | 17         |
| Cu                             | 0        | 0          | 0        | 0        | 0          |
| Zn                             | 55       | 53         | 56       | 42       | 43         |
| Hf                             | 4        | 4          | 4        | 4        | 4          |
| Ta                             | 1.9      | 1.2        | 1.7      | 1.4      | 1.2        |
| Sc                             | 3.0      | 3.5        | 3.8      | 2.9      | 3.8        |
| La                             | 24       | 27         | 31       | 26       | 22         |
| Th                             | 14.0     | 16.0       | 19.0     | 15.0     | 11.0       |
| U                              | 4.1      | 4.3        | 7.0      | 6.3      | 4.3        |
| Li                             | 83       | 57         | 93       | 74       | 84         |
| F                              | 487      | 545        | 653      | 392      | 565        |
| As                             | 5.4      | 4.3        | 7.4      | 3.8      | 4.6        |
| Sn                             | 2        | 9          | 11       | 5        | 2          |
| W                              | 0        | 0          | 0        | 0        | 0          |



# NEW ROSS PLUTON

| SAMPLE UNIT                    | A16-1166<br>MBMG | A09-2206<br>CGLMG | A09-2207<br>CGLMG | A09-2228<br>CGLMG | A09-2231<br>CGLMG | A09-2351<br>CGLMG | A09-2360<br>CGLMG | A09-2361<br>CGLMG |
|--------------------------------|------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Major Elements (wt %)          |                  |                   |                   |                   |                   |                   |                   |                   |
| SiO <sub>2</sub>               | 72.47            | 73.84             | 74.46             | 71.44             | 72.09             | 73.65             | 72.30             | 74.79             |
| Al <sub>2</sub> O <sub>3</sub> | 14.51            | 13.88             | 13.82             | 14.43             | 14.95             | 14.02             | 14.66             | 13.99             |
| Fe <sub>2</sub> O <sub>3</sub> | 2.26             | 1.70              | 1.47              | 2.65              | 1.60              | 1.92              | 2.05              | 1.38              |
| CaO                            | 0.71             | 0.70              | 0.38              | 0.39              | 0.52              | 0.75              | 1.21              | 0.37              |
| MgO                            | 1.08             | 0.92              | 0.76              | 1.31              | 1.04              | 1.07              | 1.14              | 0.82              |
| Na <sub>2</sub> O              | 3.58             | 2.98              | 3.45              | 3.26              | 3.32              | 3.13              | 3.93              | 3.21              |
| K <sub>2</sub> O               | 4.67             | 4.73              | 4.32              | 4.68              | 4.76              | 4.75              | 3.92              | 4.65              |
| TiO <sub>2</sub>               | 0.31             | 0.19              | 0.11              | 0.31              | 0.21              | 0.21              | 0.24              | 0.14              |
| P <sub>2</sub> O <sub>5</sub>  | 0.28             | 0.27              | 0.33              | 0.23              | 0.30              | 0.18              | 0.22              | 0.23              |
| MnO                            | 0.05             | 0.03              | 0.03              | 0.06              | 0.04              | 0.05              | 0.05              | 0.04              |
| H <sub>2</sub> O               | 0.60             | 0.40              | 0.70              | 1.00              | 0.60              | 0.40              | 0.40              | 0.40              |
| Normative Mineralogy           |                  |                   |                   |                   |                   |                   |                   |                   |
| Q                              | 31.44            | 36.56             | 37.01             | 32.82             | 33.11             | 34.65             | 30.84             | 37.08             |
| OR                             | 27.65            | 28.19             | 25.76             | 28.03             | 28.49             | 28.17             | 23.25             | 27.61             |
| AB                             | 30.31            | 25.41             | 29.43             | 27.93             | 28.42             | 26.55             | 33.34             | 27.26             |
| AN                             | 1.69             | 1.72              | 0.00              | 0.43              | 0.62              | 2.55              | 4.58              | 0.33              |
| C                              | 2.94             | 3.25              | 3.49              | 3.89              | 4.15              | 2.80              | 2.28              | 3.56              |
| EN                             | 2.69             | 2.31              | 1.91              | 3.30              | 2.62              | 2.67              | 2.85              | 2.05              |
| IL                             | 0.11             | 0.06              | 0.06              | 0.13              | 0.09              | 0.11              | 0.11              | 0.09              |
| HM                             | 2.26             | 1.71              | 1.48              | 2.68              | 1.62              | 1.93              | 2.06              | 1.39              |
| RU                             | 0.25             | 0.16              | 0.08              | 0.25              | 0.17              | 0.15              | 0.18              | 0.10              |
| AP                             | 0.65             | 0.63              | 0.77              | 0.54              | 0.70              | 0.42              | 0.51              | 0.54              |
| A/CNK                          | 1.19             | 1.23              | 1.25              | 1.30              | 1.29              | 1.20              | 1.14              | 1.27              |
| TTDI                           | 89.40            | 90.15             | 92.20             | 88.78             | 90.03             | 89.37             | 87.44             | 91.95             |
| Col. Ind.                      | 5.06             | 4.09              | 3.45              | 6.12              | 4.33              | 4.70              | 5.01              | 3.52              |
| Trace Elements (ppm*)          |                  |                   |                   |                   |                   |                   |                   |                   |
| Ba                             | 292              | 271               | 52                | 410               | 311               | 224               | 412               | 140               |
| Rb                             | 310              | 294               | 676               | 216               | 236               | 260               | 280               | 348               |
| Sr                             | 57               | 52                | 17                | 64                | 51                | 53                | 135               | 31                |
| Zr                             | 140              | 94                | 58                | 112               | 77                | 84                | 113               | 52                |
| Nb                             | 14               | 14                | 24                | 11                | 12                | 10                | 11                | 10                |
| V                              | 11               | 11                | 3                 | 22                | 11                | 11                | 13                | 0                 |
| Y                              | 20               | 20                | 26                | 23                | 14                | 27                | 26                | 22                |
| Ga                             | 20               | 22                | 25                | 17                | 20                | 16                | 16                | 18                |
| Cu                             | 0                | 0                 | 11                | 0                 | 0                 | 0                 | 0                 | 0                 |
| Zn                             | 56               | 53                | 114               | 32                | 47                | 40                | 53                | 39                |
| Hf                             | 3                | 3                 | 1                 | 4                 | 3                 | 3                 | 5                 | 2                 |
| Ta                             | 2.1              | 2.0               | 4.6               | 1.9               | 1.1               | 1.4               | 2.0               | 2.1               |
| Sc                             | 3.7              | 2.3               | 2.2               | 5.0               | 2.9               | 4.2               | 3.8               | 3.1               |
| La                             | 26               | 18                | 7                 | 17                | 14                | 18                | 26                | 11                |
| Th                             | 20.0             | 12.0              | 8.1               | 9.1               | 9.0               | 11.0              | 12.0              | 7.3               |
| U                              | 3.2              | 2.9               | 24.8              | 4.3               | 2.9               | 3.5               | 3.2               | 8.3               |
| Li                             | 104              | 97                | 431               | 68                | 99                | 86                | 162               | 109               |
| F                              | 1300             | 1250              | 4500              | 450               | 510               | 615               | 1165              | 770               |
| As                             | 3.4              | 4.7               | 1.3               | 1.2               | 1.8               | 1.9               | 0.9               | 1.5               |
| Sn                             | 13               | 12                | 41                | 10                | 16                | 6                 | 11                | 10                |
| W                              | 2                | 2                 | 11                | 2                 | 3                 | 0                 | 5                 | 3                 |

## NRP cont.

| SAMPLE<br>UNIT | A09-2369<br>CGLMG | A09-2372<br>CGLMG | A09-2377<br>CGLMG | A09-2378<br>CGLMG | A09-2382<br>CGLMG | A09-2386<br>CGLMG | A09-2388<br>CGLMG | A09-2389<br>CGLMG |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| SIO2           | 74.52             | 73.01             | 74.09             | 72.68             | 74.14             | 74.93             | 73.44             | 75.25             |
| AL2O3          | 13.99             | 14.13             | 13.79             | 13.76             | 13.65             | 13.38             | 14.20             | 13.47             |
| FE2O3          | 1.68              | 2.31              | 1.87              | 2.56              | 2.11              | 1.83              | 1.76              | 1.20              |
| CAO            | 0.29              | 0.57              | 0.50              | 0.91              | 0.67              | 0.52              | 0.83              | 0.46              |
| MGO            | 0.92              | 1.03              | 0.92              | 1.13              | 1.02              | 0.89              | 0.96              | 0.86              |
| NA2O           | 3.91              | 3.43              | 3.65              | 3.38              | 3.04              | 3.16              | 2.87              | 3.25              |
| K2O            | 4.27              | 4.68              | 4.90              | 4.70              | 4.62              | 4.59              | 5.10              | 4.82              |
| TIO2           | 0.16              | 0.30              | 0.16              | 0.34              | 0.22              | 0.14              | 0.22              | 0.14              |
| P2O5           | 0.27              | 0.27              | 0.17              | 0.24              | 0.17              | 0.15              | 0.23              | 0.12              |
| MNO            | 0.04              | 0.05              | 0.07              | 0.05              | 0.06              | 0.06              | 0.03              | 0.04              |
| H2O            | 0.74              | 0.57              | 0.39              | 0.21              | 0.20              | 0.10              | 0.24              | 0.48              |
| Q              | 34.01             | 33.21             | 32.09             | 32.14             | 36.39             | 37.08             | 34.77             | 36.09             |
| OR             | 25.23             | 27.74             | 28.95             | 27.87             | 27.41             | 27.25             | 30.28             | 28.62             |
| AB             | 33.04             | 29.08             | 30.84             | 28.67             | 25.80             | 26.83             | 24.37             | 27.60             |
| AN             | 0.00              | 1.06              | 1.37              | 2.95              | 2.22              | 1.60              | 2.62              | 1.50              |
| C              | 2.93              | 3.04              | 1.97              | 2.03              | 2.84              | 2.63              | 3.01              | 2.36              |
| EN             | 2.29              | 2.57              | 2.29              | 2.82              | 2.55              | 2.22              | 2.40              | 2.15              |
| IL             | 0.09              | 0.11              | 0.15              | 0.11              | 0.13              | 0.13              | 0.06              | 0.09              |
| HM             | 1.68              | 2.32              | 1.87              | 2.57              | 2.12              | 1.84              | 1.77              | 1.20              |
| RU             | 0.11              | 0.24              | 0.08              | 0.28              | 0.15              | 0.07              | 0.19              | 0.10              |
| AP             | 0.63              | 0.63              | 0.39              | 0.56              | 0.40              | 0.35              | 0.54              | 0.28              |
| A/CNK          | 1.21              | 1.20              | 1.13              | 1.12              | 1.22              | 1.20              | 1.21              | 1.18              |
| TTDI           | 92.28             | 90.04             | 91.88             | 88.68             | 89.60             | 91.15             | 89.42             | 92.32             |
| Col. ind       | 4.05              | 4.99              | 4.31              | 5.49              | 4.79              | 4.19              | 4.23              | 3.44              |
| Ba             | 151               | 275               | 161               | 292               | 136               | 101               | 392               | 249               |
| Rb             | 240               | 289               | 308               | 296               | 278               | 304               | 245               | 194               |
| Sr             | 37                | 52                | 37                | 63                | 45                | 32                | 70                | 54                |
| Zr             | 69                | 118               | 77                | 134               | 91                | 73                | 112               | 60                |
| Nb             | 10                | 13                | 10                | 12                | 10                | 10                | 11                | 6                 |
| V              | 6                 | 13                | 9                 | 19                | 11                | 5                 | 7                 | 7                 |
| Y              | 18                | 30                | 38                | 33                | 37                | 35                | 27                | 21                |
| Ga             | 18                | 17                | 17                | 18                | 18                | 15                | 20                | 15                |
| Cu             | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 5                 |
| Zn             | 19                | 55                | 44                | 55                | 51                | 59                | 40                | 36                |
| Hf             | 3                 | 4                 | 3                 | 5                 | 3                 | 3                 | 4                 | 2                 |
| Ta             | 2.0               | 2.0               | 1.8               | 1.9               | 1.7               | 2.2               | 1.1               | 1.3               |
| Sc             | 3.5               | 5.0               | 3.8               | 5.1               | 4.5               | 3.6               | 2.2               | 3.0               |
| La             | 7                 | 26                | 13                | 30                | 16                | 11                | 27                | 8                 |
| Th             | 6.1               | 18.0              | 9.0               | 20.6              | 11.0              | 9.0               | 18.0              | 4.8               |
| U              | 8.4               | 5.1               | 3.3               | 4.1               | 3.9               | 5.2               | 3.0               | 5.4               |
| Li             | 21                | 61                | 47                | 39                | 126               | 192               | 55                | 47                |
| F              | 420               | 1165              | 875               | 1220              | 1020              | 1495              | 620               | 150               |
| As             | 1.6               | 2.4               | 12.0              | 2.1               | 5.9               | 1.6               | 1.7               | 1.6               |
| Sn             | 13                | 5                 | 16                | 7                 | 10                | 9                 | 9                 | 5                 |
| W              | 3                 | 2                 | 2                 | 0                 | 1                 | 2                 | 1                 | 2                 |

## NRP cont.

| SAMPLE UNIT | A09-2398<br>CGLMG | A10-3017-2<br>CGLMG | A10-3020<br>CGLMG | A10-3025<br>CGLMG | A10-3033<br>CGLMG | A16-1167<br>CGLMG | A16-1170<br>CGLMG | A16-1174<br>CGLMG |
|-------------|-------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| SIO2        | 74.25             | 74.11               | 73.12             | 72.31             | 72.95             | 74.38             | 72.98             | 74.80             |
| AL2O3       | 13.32             | 14.11               | 14.33             | 14.72             | 13.70             | 14.20             | 14.58             | 13.00             |
| FE2O3       | 1.85              | 1.27                | 1.78              | 1.96              | 2.54              | 1.61              | 2.16              | 1.96              |
| CAO         | 0.51              | 0.31                | 0.36              | 0.85              | 0.61              | 0.48              | 0.62              | 0.34              |
| MGO         | 0.90              | 0.80                | 0.87              | 1.17              | 1.12              | 0.84              | 0.90              | 0.82              |
| NA2O        | 3.44              | 2.98                | 3.46              | 3.43              | 2.80              | 3.62              | 3.83              | 3.48              |
| K2O         | 4.39              | 4.91                | 4.53              | 4.46              | 4.76              | 4.52              | 4.58              | 4.81              |
| TIO2        | 0.20              | 0.11                | 0.19              | 0.25              | 0.33              | 0.12              | 0.18              | 0.15              |
| P2O5        | 0.29              | 0.28                | 0.27              | 0.22              | 0.22              | 0.23              | 0.18              | 0.19              |
| MNO         | 0.04              | 0.02                | 0.04              | 0.06              | 0.05              | 0.05              | 0.06              | 0.05              |
| H2O         | 0.50              | 0.73                | 0.63              | 0.54              | 0.47              | 0.60              | 0.50              | 0.50              |
| Q           | 36.10             | 37.16               | 34.70             | 32.51             | 36.41             | 34.36             | 30.97             | 34.86             |
| OR          | 26.18             | 29.35               | 27.08             | 26.53             | 28.42             | 26.72             | 27.07             | 28.57             |
| AB          | 29.34             | 25.48               | 29.58             | 29.19             | 23.91             | 30.61             | 32.38             | 29.56             |
| AN          | 0.64              | 0.00                | 0.02              | 2.79              | 1.60              | 0.88              | 1.90              | 0.44              |
| C           | 2.70              | 3.93                | 3.76              | 3.25              | 3.39              | 3.03              | 2.62              | 1.91              |
| EN          | 2.26              | 2.01                | 2.19              | 2.93              | 2.82              | 2.09              | 2.24              | 2.05              |
| IL          | 0.09              | 0.04                | 0.09              | 0.13              | 0.11              | 0.11              | 0.13              | 0.11              |
| HM          | 1.87              | 1.28                | 1.80              | 1.97              | 2.56              | 1.61              | 2.16              | 1.97              |
| RU          | 0.16              | 0.09                | 0.15              | 0.18              | 0.28              | 0.06              | 0.11              | 0.09              |
| AP          | 0.68              | 0.66                | 0.63              | 0.51              | 0.52              | 0.53              | 0.42              | 0.44              |
| A/CNK       | 1.17              | 1.31                | 1.27              | 1.23              | 1.26              | 1.21              | 1.18              | 1.13              |
| TTDI        | 91.62             | 91.99               | 91.36             | 88.23             | 88.73             | 91.69             | 90.43             | 92.98             |
| Col. Ind.   | 4.21              | 3.34                | 4.07              | 5.03              | 5.49              | 3.81              | 4.53              | 4.13              |
| Ba          | 144               | 140                 | 173               | 254               | 249               | 83                | 230               | 120               |
| Rb          | 336               | 353                 | 303               | 210               | 261               | 275               | 275               | 274               |
| Sr          | 34                | 29                  | 43                | 76                | 61                | 22                | 53                | 33                |
| Zr          | 84                | 54                  | 73                | 86                | 121               | 55                | 84                | 77                |
| Nb          | 15                | 10                  | 12                | 9                 | 11                | 11                | 11                | 10                |
| V           | 10                | 0                   | 8                 | 12                | 16                | 2                 | 11                | 6                 |
| Y           | 20                | 20                  | 24                | 22                | 26                | 17                | 26                | 25                |
| Ga          | 24                | 20                  | 18                | 17                | 19                | 23                | 20                | 22                |
| Cu          | 0                 | 0                   | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 |
| Zn          | 61                | 44                  | 49                | 49                | 57                | 40                | 49                | 60                |
| Hf          | 3                 | 2                   | 3                 | 2                 | 4                 | 1                 | 3                 | 3                 |
| Ta          | 2.0               | 2.2                 | 2.3               | 1.4               | 1.8               | 1.7               | 1.4               | 1.3               |
| Sc          | 2.7               | 2.2                 | 3.5               | 4.5               | 4.8               | 2.0               | 3.8               | 2.5               |
| La          | 17                | 9                   | 11                | 15                | 20                | 9                 | 16                | 11                |
| Th          | 12.0              | 6.1                 | 6.3               | 7.7               | 12.0              | 6.2               | 8.6               | 7.5               |
| U           | 3.3               | 3.5                 | 4.3               | 3.0               | 2.9               | 3.6               | 3.8               | 3.8               |
| Li          | 135               | 35                  | 36                | 48                | 39                | 74                | 99                | 67                |
| F           | 1100              | 1030                | 900               | 540               | 990               | 660               | 720               | 590               |
| As          | 1.5               | 1.7                 | 4.1               | 2.0               | 1.9               | 1.8               | 0.8               | 3.7               |
| Sn          | 14                | 13                  | 22                | 10                | 11                | 12                | 13                | 16                |
| W           | 3                 | 3                   | 8                 | 0                 | 1                 | 3                 | 1                 | 4                 |

## NRP cont.

| SAMPLE<br>UNIT                 | A16-1213<br>CGLMG | A16-1217-1<br>CGLMG | A16-1221<br>CGLMG | A16-3049<br>CGLMG | A09-2153-3<br>FGLMG | A09-2154<br>FGLMG | A09-2155<br>FGLMG | A09-2161<br>FGLMG |
|--------------------------------|-------------------|---------------------|-------------------|-------------------|---------------------|-------------------|-------------------|-------------------|
| SiO <sub>2</sub>               | 73.49             | 73.70               | 73.50             | 72.09             | 73.44               | 75.10             | 73.80             | 73.97             |
| Al <sub>2</sub> O <sub>3</sub> | 14.54             | 14.33               | 14.33             | 14.08             | 14.70               | 14.07             | 14.02             | 13.33             |
| Fe <sub>2</sub> O <sub>3</sub> | 1.40              | 1.32                | 1.66              | 2.00              | 1.24                | 0.99              | 1.72              | 0.79              |
| CaO                            | 0.38              | 0.36                | 0.43              | 0.71              | 0.36                | 0.31              | 0.41              | 1.31              |
| MgO                            | 0.77              | 0.73                | 0.86              | 1.00              | 0.88                | 0.74              | 0.77              | 0.78              |
| Na <sub>2</sub> O              | 3.49              | 4.39                | 3.23              | 3.47              | 3.83                | 3.40              | 2.97              | 3.57              |
| K <sub>2</sub> O               | 4.93              | 4.18                | 4.63              | 5.01              | 4.57                | 4.27              | 4.84              | 4.70              |
| TiO <sub>2</sub>               | 0.11              | 0.09                | 0.18              | 0.21              | 0.13                | 0.07              | 0.15              | 0.14              |
| P <sub>2</sub> O <sub>5</sub>  | 0.30              | 0.38                | 0.31              | 0.17              | 0.30                | 0.36              | 0.31              | 0.21              |
| MnO                            | 0.03              | 0.04                | 0.03              | 0.05              | 0.04                | 0.02              | 0.04              | 0.02              |
| H <sub>2</sub> O               | 0.40              | 0.89                | 0.60              | 0.40              | 0.53                | 0.49              | 0.67              | 1.30              |
| Q                              | 33.34             | 31.17               | 35.95             | 30.55             | 32.50               | 38.05             | 37.19             | 32.20             |
| OR                             | 29.32             | 24.81               | 27.62             | 30.00             | 27.16               | 25.39             | 28.91             | 28.13             |
| AB                             | 29.69             | 37.27               | 27.56             | 29.72             | 32.56               | 28.91             | 25.37             | 30.57             |
| AN                             | 0.00              | 0.00                | 0.10              | 2.44              | 0.00                | 0.00              | 0.00              | 5.19              |
| C                              | 3.48              | 2.59                | 4.00              | 2.09              | 3.47                | 3.87              | 3.93              | 0.49              |
| EN                             | 1.93              | 1.82                | 2.16              | 2.52              | 2.20                | 1.85              | 1.94              | 1.97              |
| IL                             | 0.06              | 0.09                | 0.06              | 0.11              | 0.09                | 0.04              | 0.09              | 0.04              |
| HM                             | 1.41              | 1.32                | 1.67              | 2.02              | 1.25                | 1.00              | 1.74              | 0.80              |
| RU                             | 0.08              | 0.05                | 0.15              | 0.16              | 0.09                | 0.05              | 0.11              | 0.12              |
| AP                             | 0.70              | 0.88                | 0.73              | 0.40              | 0.70                | 0.84              | 0.73              | 0.49              |
| A/CNK                          | 1.24              | 1.16                | 1.29              | 1.13              | 1.24                | 1.31              | 1.29              | 1.00              |
| TTDI                           | 92.35             | 93.25               | 91.13             | 90.27             | 92.22               | 92.35             | 91.48             | 90.90             |
| Col. Ind.                      | 3.40              | 3.23                | 3.90              | 4.65              | 3.53                | 2.89              | 3.76              | 2.81              |
| Ba                             | 86                | 48                  | 164               | 277               | 210                 | 19                | 150               | 591               |
| Rb                             | 374               | 692                 | 347               | 233               | 277                 | 521               | 487               | 246               |
| Sr                             | 25                | 32                  | 30                | 66                | 43                  | 10                | 28                | 63                |
| Zr                             | 62                | 44                  | 79                | 92                | 53                  | 32                | 78                | 73                |
| Nb                             | 14                | 24                  | 16                | 11                | 12                  | 15                | 14                | 7                 |
| V                              | 4                 | 10                  | 6                 | 10                | 0                   | 0                 | 5                 | 0                 |
| Y                              | 20                | 35                  | 19                | 25                | 19                  | 26                | 32                | 32                |
| Ga                             | 19                | 26                  | 25                | 20                | 17                  | 23                | 22                | 15                |
| Cu                             | 0                 | 0                   | 0                 | 0                 | 0                   | 0                 | 0                 | 8                 |
| Zn                             | 71                | 67                  | 48                | 42                | 32                  | 48                | 59                | 12                |
| Hf                             | 2                 | 1                   | 3                 | 3                 | 2                   | 1                 | 3                 | 3                 |
| Ta                             | 0.9               | 5.6                 | 6.8               | 1.2               | 2.0                 | 3.6               | 3.1               | 1.6               |
| Sc                             | 1.7               | 2.5                 | 2.5               | 3.7               | 2.9                 | 2.2               | 2.5               | 2.1               |
| La                             | 8                 | 6                   | 13                | 19                | 7                   | 3                 | 14                | 40                |
| Th                             | 5.5               | 5.7                 | 11.0              | 10.0              | 4.0                 | 3.4               | 12.0              | 8.4               |
| U                              | 7.1               | 5.8                 | 16.0              | 3.3               | 2.1                 | 14.0              | 13.0              | 6.2               |
| Li                             | 209               | 312                 | 123               | 75                | 90                  | 182               | 129               | 12                |
| F                              | 1800              | 3875                | 1650              | 570               | 620                 | 1825              | 1825              | 7680              |
| As                             | 0.6               | 1.1                 | 2.9               | 1.5               | 3.3                 | 1.5               | 1.3               | 5.3               |
| Sn                             | 24                | 40                  | 16                | 17                | 16                  | 16                | 12                | 5                 |
| W                              | 3                 | 13                  | 5                 | 1                 | 4                   | 6                 | 6                 | 3                 |

## NRP cont.

| SAMPLE UNIT                    | A09-2177-1<br>FGLMG | A09-2181<br>FGLMG | A09-2192<br>FGLMG | A09-2193<br>FGLMG | A09-2196<br>FGLMG | A09-2211-1<br>FGLMG | A09-2212<br>FGLMG | A09-2222<br>FGLMG |
|--------------------------------|---------------------|-------------------|-------------------|-------------------|-------------------|---------------------|-------------------|-------------------|
| SiO <sub>2</sub>               | 75.87               | 74.12             | 74.64             | 74.56             | 74.09             | 74.81               | 73.35             | 73.10             |
| Al <sub>2</sub> O <sub>3</sub> | 13.09               | 14.21             | 13.98             | 14.14             | 14.06             | 13.91               | 14.36             | 14.97             |
| Fe <sub>2</sub> O <sub>3</sub> | 1.58                | 1.41              | 0.93              | 1.13              | 1.65              | 1.24                | 1.73              | 1.30              |
| CaO                            | 0.31                | 0.35              | 0.25              | 0.35              | 0.46              | 0.24                | 0.39              | 0.37              |
| MgO                            | 0.81                | 0.84              | 0.80              | 0.76              | 0.82              | 0.77                | 0.97              | 0.89              |
| Na <sub>2</sub> O              | 3.01                | 4.56              | 3.41              | 3.35              | 3.43              | 3.62                | 3.32              | 3.38              |
| K <sub>2</sub> O               | 4.27                | 4.33              | 4.36              | 4.60              | 4.81              | 4.22                | 4.63              | 4.80              |
| TiO <sub>2</sub>               | 0.12                | 0.11              | 0.04              | 0.07              | 0.18              | 0.06                | 0.15              | 0.17              |
| P <sub>2</sub> O <sub>5</sub>  | 0.27                | 0.36              | 0.24              | 0.24              | 0.31              | 0.22                | 0.19              | 0.32              |
| MnO                            | 0.03                | 0.03              | 0.05              | 0.07              | 0.03              | 0.07                | 0.06              | 0.03              |
| H <sub>2</sub> O               | 0.62                | 0.40              | 0.49              | 0.58              | 0.54              | 0.77                | 0.63              | 0.60              |
| Q                              | 41.04               | 29.62             | 37.37             | 36.51             | 34.44             | 36.73               | 34.85             | 33.93             |
| OR                             | 25.41               | 25.50             | 26.11             | 27.41             | 28.50             | 25.16               | 27.62             | 28.57             |
| AB                             | 25.62               | 38.41             | 29.21             | 28.55             | 29.07             | 30.87               | 28.33             | 28.78             |
| AN                             | 0.00                | 0.00              | 0.00              | 0.17              | 0.25              | 0.00                | 0.70              | 0.00              |
| C                              | 3.53                | 2.01              | 3.69              | 3.61              | 3.12              | 3.41                | 3.66              | 4.24              |
| EN                             | 2.03                | 2.08              | 2.02              | 1.91              | 2.05              | 1.93                | 2.44              | 2.23              |
| IL                             | 0.06                | 0.06              | 0.08              | 0.13              | 0.06              | 0.11                | 0.13              | 0.06              |
| HM                             | 1.59                | 1.40              | 0.91              | 1.12              | 1.65              | 1.21                | 1.74              | 1.31              |
| RU                             | 0.09                | 0.08              | 0.00              | 0.00              | 0.15              | 0.00                | 0.08              | 0.14              |
| AP                             | 0.63                | 0.83              | 0.56              | 0.56              | 0.72              | 0.51                | 0.44              | 0.75              |
| A/CNK                          | 1.29                | 1.11              | 1.30              | 1.27              | 1.20              | 1.27                | 1.28              | 1.31              |
| TTDI                           | 92.07               | 93.53             | 92.69             | 92.47             | 92.00             | 92.76               | 90.60             | 91.28             |
| Col. Ind.                      | 3.68                | 3.55              | 3.05              | 3.19              | 3.76              | 3.31                | 4.31              | 3.60              |
| Ba                             | 44                  | 29                | 32                | 66                | 139               | 34                  | 155               | 292               |
| Rb                             | 499                 | 572               | 321               | 314               | 416               | 390                 | 288               | 356               |
| Sr                             | 10                  | 15                | 9                 | 18                | 31                | 8                   | 34                | 37                |
| Zr                             | 69                  | 53                | 29                | 36                | 81                | 41                  | 63                | 66                |
| Nb                             | 17                  | 21                | 7                 | 8                 | 14                | 10                  | 8                 | 9                 |
| V                              | 0                   | 3                 | 0                 | 0                 | 0                 | 0                   | 0                 | 5                 |
| Y                              | 32                  | 20                | 22                | 21                | 29                | 29                  | 28                | 17                |
| Ga                             | 21                  | 25                | 17                | 19                | 23                | 18                  | 18                | 21                |
| Cu                             | 0                   | 0                 | 0                 | 0                 | 0                 | 0                   | 0                 | 0                 |
| Zn                             | 60                  | 59                | 13                | 30                | 63                | 36                  | 28                | 49                |
| Hf                             | 3                   | 1                 | 1                 | 2                 | 3                 | 2                   | 3                 | 1                 |
| Ta                             | 3.6                 | 5.1               | 2.7               | 2.9               | 3.1               | 3.2                 | 1.8               | 1.6               |
| Sc                             | 2.1                 | 3.7               | 2.7               | 3.2               | 2.8               | 3.5                 | 3.6               | 1.9               |
| La                             | 9                   | 6                 | 2                 | 5                 | 14                | 4                   | 10                | 11                |
| Th                             | 11.0                | 6.3               | 2.7               | 3.2               | 11.0              | 4.8                 | 6.7               | 8.7               |
| U                              | 28.6                | 24.1              | 10.0              | 3.1               | 15.0              | 7.6                 | 4.6               | 5.1               |
| Li                             | 96                  | 342               | 16                | 46                | 73                | 88                  | 68                | 221               |
| F                              | 2535                | 3200              | 385               | 495               | 2350              | 855                 | 495               | 1400              |
| As                             | 1.6                 | 19.0              | 65.5              | 4.5               | 2.7               | 7.0                 | 1.3               | 4.9               |
| Sn                             | 22                  | 34                | 7                 | 11                | 21                | 23                  | 12                | 20                |
| W                              | 5                   | 14                | 4                 | 2                 | 6                 | 7                   | 3                 | 3                 |

## NRP cont.

| SAMPLE<br>UNIT | A09-2224<br>FGLMG | A09-2350<br>FGLMG | A09-2352<br>FGLMG | A09-2353<br>FGLMG | A09-2354<br>FGLMG | A09-2365<br>FGLMG | A09-2366<br>FGLMG | A09-2373<br>FGLMG |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| SiO2           | 73.51             | 74.98             | 74.21             | 75.22             | 73.18             | 74.65             | 75.42             | 75.24             |
| Al2O3          | 14.67             | 14.24             | 14.08             | 13.69             | 14.17             | 13.81             | 13.71             | 14.00             |
| Fe2O3          | 1.34              | 1.32              | 1.03              | 1.55              | 1.81              | 1.67              | 0.73              | 1.16              |
| CaO            | 0.34              | 0.28              | 0.43              | 0.31              | 0.68              | 0.35              | 0.30              | 0.30              |
| MgO            | 2.16              | 0.81              | 0.83              | 0.83              | 0.97              | 0.87              | 0.80              | 0.80              |
| Na2O           | 3.49              | 3.53              | 4.75              | 3.82              | 3.61              | 3.32              | 2.91              | 3.80              |
| K2O            | 4.67              | 4.38              | 4.46              | 4.49              | 4.58              | 4.43              | 5.30              | 4.48              |
| TiO2           | 0.14              | 0.06              | 0.10              | 0.12              | 0.19              | 0.14              | 0.06              | 0.07              |
| P2O5           | 0.30              | 0.24              | 0.36              | 0.24              | 0.21              | 0.22              | 0.15              | 0.28              |
| MNO            | 0.04              | 0.04              | 0.03              | 0.04              | 0.05              | 0.04              | 0.03              | 0.04              |
| H2O            | 0.40              | 0.30              | 0.60              | 0.20              | 0.40              | 0.40              | 0.48              | 0.51              |
| Q              | 31.87             | 36.49             | 28.17             | 34.45             | 32.51             | 37.13             | 37.00             | 34.70             |
| OR             | 27.43             | 25.93             | 26.30             | 26.47             | 27.24             | 26.34             | 31.54             | 26.44             |
| AB             | 29.32             | 29.89             | 40.06             | 32.22             | 30.71             | 28.23             | 24.77             | 32.07             |
| AN             | 0.00              | 0.00              | 0.00              | 0.00              | 2.01              | 0.30              | 0.51              | 0.00              |
| C              | 3.84              | 3.69              | 1.43              | 2.53              | 2.55              | 3.46              | 3.01              | 2.89              |
| EN             | 5.34              | 2.02              | 2.06              | 2.06              | 2.43              | 2.18              | 2.00              | 1.99              |
| IL             | 0.08              | 0.09              | 0.06              | 0.09              | 0.11              | 0.09              | 0.06              | 0.09              |
| HM             | 1.33              | 1.32              | 1.03              | 1.55              | 1.82              | 1.68              | 0.73              | 1.16              |
| RU             | 0.09              | 0.01              | 0.07              | 0.07              | 0.13              | 0.10              | 0.03              | 0.02              |
| AP             | 0.69              | 0.56              | 0.83              | 0.55              | 0.49              | 0.51              | 0.35              | 0.65              |
| A/CNK          | 1.29              | 1.29              | 1.05              | 1.17              | 1.17              | 1.27              | 1.24              | 1.20              |
| TTDI           | 88.62             | 92.31             | 94.52             | 93.15             | 90.46             | 91.69             | 93.30             | 93.21             |
| Col. Ind.      | 6.76              | 3.43              | 3.15              | 3.69              | 4.36              | 3.94              | 2.80              | 3.23              |
| Ba             | 212               | 15                | 155               | 72                | 158               | 78                | 100               | 14                |
| Rb             | 321               | 290               | 296               | 319               | 273               | 296               | 235               | 409               |
| Sr             | 31                | 0                 | 30                | 23                | 48                | 26                | 26                | 9                 |
| Zr             | 59                | 26                | 50                | 57                | 81                | 67                | 24                | 26                |
| Nb             | 14                | 8                 | 9                 | 10                | 10                | 10                | 6                 | 11                |
| V              | 2                 | 0                 | 0                 | 0                 | 8                 | 0                 | 6                 | 0                 |
| Y              | 17                | 20                | 22                | 26                | 26                | 27                | 22                | 24                |
| Ga             | 20                | 18                | 18                | 20                | 18                | 19                | 17                | 22                |
| Cu             | 0                 | 5                 | 0                 | 0                 | 0                 | 0                 | 10                | 0                 |
| Zn             | 46                | 32                | 17                | 42                | 44                | 33                | 41                | 51                |
| Hf             | 1                 | 0                 | 1                 | 3                 | 3                 | 3                 | 0                 | 1                 |
| Ta             | 2.6               | 1.7               | 2.2               | 2.5               | 1.6               | 1.7               | 1.0               | 2.8               |
| Sc             | 2.9               | 2.3               | 3.1               | 2.9               | 3.7               | 3.2               | 1.9               | 2.2               |
| La             | 10                | 2                 | 6                 | 10                | 15                | 10                | 4                 | 2                 |
| Th             | 6.6               | 3.1               | 4.6               | 7.1               | 8.2               | 7.2               | 2.2               | 3.0               |
| U              | 4.4               | 13.0              | 6.9               | 7.4               | 7.8               | 5.9               | 6.0               | 16.0              |
| Li             | 156               | 70                | 52                | 90                | 76                | 73                | 6                 | 18                |
| F              | 1150              | 605               | 580               | 755               | 760               | 645               | 155               | 675               |
| As             | 1.6               | 2.3               | 3.9               | 1.6               | 2.5               | 2.3               | 15.0              | 8.4               |
| Sn             | 14                | 14                | 17                | 13                | 10                | 13                | 9                 | 18                |
| W              | 2                 | 41                | 4                 | 5                 | 2                 | 2                 | 2                 | 5                 |



## NRP cont.

| SAMPLE<br>UNIT | A09-2374<br>FGLMG | A09-2380<br>FGLMG | A09-2383<br>FGLMG | A09-2384<br>FGLMG | A09-2390<br>FGLMG | A09-2392<br>FGLMG | A09-2399<br>FGLMG | A10-3008<br>FGLMG |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| SiO2           | 74.78             | 75.37             | 74.38             | 74.32             | 74.84             | 75.24             | 74.51             | 74.69             |
| AL2O3          | 14.27             | 14.26             | 13.71             | 14.52             | 14.42             | 14.35             | 13.96             | 13.86             |
| FE2O3          | 1.22              | 0.60              | 1.57              | 0.83              | 0.70              | 0.54              | 1.42              | 1.48              |
| CAO            | 0.30              | 0.24              | 0.38              | 0.24              | 0.31              | 0.32              | 0.33              | 0.30              |
| MGO            | 0.72              | 0.67              | 0.96              | 0.75              | 0.68              | 0.76              | 0.74              | 0.80              |
| NA2O           | 3.93              | 3.76              | 3.13              | 4.28              | 3.75              | 3.75              | 2.95              | 3.54              |
| K2O            | 4.06              | 4.29              | 4.46              | 4.37              | 3.92              | 3.94              | 4.14              | 4.64              |
| TiO2           | 0.06              | 0.04              | 0.11              | 0.03              | 0.05              | 0.05              | 0.10              | 0.11              |
| P2O5           | 0.32              | 0.17              | 0.18              | 0.21              | 0.29              | 0.26              | 0.34              | 0.26              |
| MNO            | 0.04              | 0.03              | 0.09              | 0.04              | 0.05              | 0.05              | 0.03              | 0.04              |
| H2O            | 0.60              | 0.59              | 0.70              | 0.33              | 0.54              | 0.41              | 0.70              | 0.60              |
| Q              | 35.36             | 36.24             | 37.74             | 31.68             | 37.34             | 37.47             | 40.94             | 35.21             |
| OR             | 24.06             | 25.52             | 26.66             | 25.95             | 23.40             | 23.47             | 24.83             | 27.51             |
| AB             | 33.31             | 31.99             | 26.76             | 36.35             | 32.02             | 31.96             | 25.30             | 30.02             |
| AN             | 0.00              | 0.08              | 0.71              | 0.00              | 0.00              | 0.00              | 0.00              | 0.00              |
| C              | 3.41              | 3.42              | 3.51              | 2.76              | 4.04              | 3.94              | 4.69              | 3.02              |
| EN             | 1.80              | 1.68              | 2.42              | 1.87              | 1.71              | 1.91              | 1.87              | 2.00              |
| IL             | 0.09              | 0.06              | 0.19              | 0.06              | 0.10              | 0.10              | 0.07              | 0.09              |
| HM             | 1.22              | 0.60              | 1.59              | 0.80              | 0.69              | 0.53              | 1.44              | 1.48              |
| RU             | 0.01              | 0.01              | 0.01              | 0.00              | 0.00              | 0.00              | 0.07              | 0.07              |
| AP             | 0.74              | 0.40              | 0.42              | 0.49              | 0.68              | 0.61              | 0.80              | 0.60              |
| A/CNK          | 1.25              | 1.27              | 1.29              | 1.19              | 1.31              | 1.30              | 1.41              | 1.22              |
| TTDI           | 92.72             | 93.75             | 91.15             | 93.98             | 92.76             | 92.90             | 91.07             | 92.75             |
| Col. Ind.      | 3.10              | 2.35              | 4.20              | 2.78              | 2.52              | 2.55              | 3.37              | 3.57              |
| Ba             | 12                | 23                | 72                | 17                | 33                | 28                | 20                | 67                |
| Rb             | 547               | 234               | 332               | 401               | 457               | 442               | 504               | 347               |
| Sr             | 0                 | 8                 | 22                | 6                 | 6                 | 8                 | 5                 | 17                |
| Zr             | 34                | 35                | 55                | 35                | 26                | 23                | 46                | 61                |
| Nb             | 13                | 10                | 8                 | 10                | 13                | 10                | 19                | 12                |
| V              | 0                 | 0                 | 0                 | 0                 | 0                 | 0                 | 1                 | 4                 |
| Y              | 32                | 20                | 31                | 25                | 21                | 26                | 20                | 17                |
| Ga             | 22                | 16                | 17                | 21                | 21                | 19                | 25                | 20                |
| Cu             | 0                 | 37                | 5                 | 0                 | 0                 | 0                 | 0                 | 0                 |
| Zn             | 42                | 20                | 49                | 58                | 24                | 27                | 46                | 43                |
| Hf             | 1                 | 2                 | 3                 | 2                 | 2                 | 2                 | 1                 | 1                 |
| Ta             | 3.7               | 2.7               | 2.6               | 2.7               | 3.8               | 3.1               | 4.5               | 1.2               |
| Sc             | 2.4               | 3.9               | 3.3               | 3.3               | 3.9               | 3.3               | 2.5               | 2.5               |
| La             | 3                 | 2                 | 7                 | 2                 | 0                 | 0                 | 5                 | 8                 |
| Th             | 3.7               | 3.8               | 6.3               | 4.1               | 1.8               | 1.6               | 5.0               | 5.6               |
| U              | 4.9               | 15.0              | 5.3               | 22.1              | 14.0              | 7.1               | 13.0              | 11.0              |
| Li             | 59                | 23                | 124               | 67                | 83                | 127               | 190               | 162               |
| F              | 1845              | 350               | 815               | 600               | 850               | 825               | 1900              | 1275              |
| As             | 2.0               | 17.0              | 11.0              | 22.0              | 1.6               | 3.3               | 3.7               | 8.9               |
| Sn             | 35                | 21                | 21                | 25                | 33                | 30                | 22                | 21                |
| W              | 6                 | 35                | 4                 | 6                 | 9                 | 6                 | 7                 | 4                 |

## NRP cont.

| SAMPLE UNIT                    | A10-3008-G<br>FGLMG | A10-3012<br>FGLMG | A16-1222<br>FGLMG | A16-1224<br>FGLMG | A16-1238-A<br>FGLMG | A16-1290-1<br>FGLMG | A16-3024<br>FGLMG | A16-3048<br>FGLMG |
|--------------------------------|---------------------|-------------------|-------------------|-------------------|---------------------|---------------------|-------------------|-------------------|
| SiO <sub>2</sub>               | 74.82               | 74.00             | 74.33             | 72.71             | 73.90               | 73.91               | 73.19             | 73.00             |
| Al <sub>2</sub> O <sub>3</sub> | 13.87               | 14.52             | 14.20             | 14.59             | 14.97               | 13.74               | 14.11             | 14.61             |
| Fe <sub>2</sub> O <sub>3</sub> | 1.35                | 1.10              | 1.15              | 0.90              | 0.86                | 1.46                | 2.11              | 1.44              |
| CaO                            | 0.27                | 0.40              | 0.32              | 0.43              | 0.34                | 0.31                | 0.32              | 0.36              |
| MgO                            | 0.68                | 0.81              | 0.74              | 0.73              | 0.80                | 0.78                | 1.24              | 0.90              |
| Na <sub>2</sub> O              | 3.46                | 3.67              | 3.74              | 4.08              | 3.83                | 4.11                | 3.03              | 3.82              |
| K <sub>2</sub> O               | 4.45                | 4.39              | 4.16              | 3.38              | 3.64                | 4.41                | 5.20              | 4.62              |
| TiO <sub>2</sub>               | 0.08                | 0.09              | 0.06              | 0.05              | 0.06                | 0.11                | 0.22              | 0.12              |
| P <sub>2</sub> O <sub>5</sub>  | 0.28                | 0.30              | 0.34              | 0.50              | 0.46                | 0.28                | 0.18              | 0.34              |
| MnO                            | 0.03                | 0.04              | 0.03              | 0.03              | 0.02                | 0.05                | 0.05              | 0.04              |
| H <sub>2</sub> O               | 0.63                | 0.40              | 0.60              | 0.80              | 0.80                | 0.45                | 0.60              | 0.60              |
| Q                              | 36.86               | 34.86             | 35.82             | 35.79             | 36.80               | 32.20               | 33.74             | 31.95             |
| OR                             | 26.48               | 26.14             | 24.81             | 20.48             | 21.72               | 26.29               | 30.87             | 27.51             |
| AB                             | 29.45               | 31.26             | 31.90             | 35.36             | 32.68               | 35.05               | 25.73             | 32.54             |
| AN                             | 0.00                | 0.02              | 0.00              | 0.00              | 0.00                | 0.00                | 0.41              | 0.00              |
| C                              | 3.38                | 3.74              | 3.57              | 4.32              | 4.77                | 2.22                | 3.35              | 3.34              |
| EN                             | 1.70                | 2.03              | 1.86              | 1.86              | 2.01                | 1.96                | 3.10              | 2.26              |
| IL                             | 0.06                | 0.09              | 0.06              | 0.07              | 0.04                | 0.11                | 0.11              | 0.09              |
| HM                             | 1.36                | 1.11              | 1.16              | 0.92              | 0.87                | 1.47                | 2.12              | 1.45              |
| RU                             | 0.05                | 0.05              | 0.03              | 0.02              | 0.04                | 0.05                | 0.16              | 0.08              |
| AP                             | 0.65                | 0.70              | 0.80              | 1.19              | 1.08                | 0.65                | 0.42              | 0.79              |
| A/CNK                          | 1.26                | 1.26              | 1.26              | 1.31              | 1.38                | 1.14                | 1.26              | 1.22              |
| TTDI                           | 92.80               | 92.26             | 92.53             | 91.63             | 91.20               | 93.54               | 90.33             | 92.00             |
| Col Ind                        | 3.13                | 3.22              | 3.08              | 2.85              | 2.92                | 3.54                | 5.32              | 3.79              |
| Ba                             | 30                  | 207               | 26                | 14                | 17                  | 63                  | 312               | 183               |
| Rb                             | 386                 | 187               | 409               | 485               | 550                 | 364                 | 248               | 248               |
| Sr                             | 8                   | 54                | 6                 | 15                | 6                   | 17                  | 53                | 37                |
| Zr                             | 47                  | 40                | 33                | 28                | 20                  | 56                  | 101               | 54                |
| Nb                             | 11                  | 10                | 13                | 25                | 34                  | 12                  | 11                | 11                |
| V                              | 0                   | 5                 | 2                 | 0                 | 0                   | 0                   | 10                | 6                 |
| Y                              | 23                  | 14                | 16                | 16                | 17                  | 23                  | 26                | 15                |
| Ga                             | 22                  | 19                | 23                | 29                | 34                  | 19                  | 23                | 20                |
| Cu                             | 57                  | 0                 | 0                 | 0                 | 0                   | 13                  | 0                 | 0                 |
| Zn                             | 66                  | 78                | 56                | 58                | 69                  | 49                  | 30                | 29                |
| Hf                             | 2                   | 1                 | 1                 | 1                 | 1                   | 2                   | 3                 | 2                 |
| Ta                             | 2.5                 | 2.4               | 2.2               | 0.8               | 1.2                 | 2.7                 | 1.6               | 2.4               |
| Sc                             | 2.3                 | 4.5               | 1.4               | 4.2               | 7.6                 | 3.0                 | 4.1               | 3.8               |
| La                             | 4                   | 5                 | 2                 | 2                 | 2                   | 7                   | 19                | 7                 |
| Th                             | 4.2                 | 1.2               | 2.2               | 1.3               | 1.0                 | 4.8                 | 10.0              | 2.9               |
| U                              | 7.6                 | 1.5               | 10.0              | 21.4              | 8.8                 | 5.0                 | 3.2               | 2.6               |
| Li                             | 87                  | 34                | 143               | 89                | 109                 | 132                 | 60                | 46                |
| F                              | 990                 | 210               | 1175              | 1150              | 1150                | 1005                | 570               | 490               |
| As                             | 7.7                 | 4.1               | 2.5               | 2.6               | 3.4                 | 6.0                 | 9.3               | 2.3               |
| Sn                             | 22                  | 12                | 19                | 20                | 31                  | 22                  | 15                | 22                |
| W                              | 6                   | 5                 | 5                 | 8                 | 10                  | 5                   | 2                 | 5                 |

NRP cont.

| SAMPLE<br>UNIT | A16-3054<br>FGLMG | A16-3056<br>FGLMG | A16-3057<br>FGLMG | D13-2065<br>FGLMG | D13-2069-2<br>FGLMG | A09-2208<br>FGLMG | A09-2210<br>FGLMG | A09-2375<br>FGLMG |
|----------------|-------------------|-------------------|-------------------|-------------------|---------------------|-------------------|-------------------|-------------------|
| SiO2           | 73.58             | 71.88             | 73.58             | 73.00             | 74.56               | 71.96             | 72.34             | 72.42             |
| Al2O3          | 14.88             | 14.44             | 13.92             | 14.46             | 13.50               | 14.70             | 14.22             | 14.23             |
| Fe2O3          | 1.75              | 2.16              | 1.77              | 1.89              | 0.87                | 1.78              | 2.52              | 2.38              |
| CaO            | 0.83              | 0.60              | 0.37              | 0.66              | 0.34                | 0.48              | 0.94              | 0.71              |
| MgO            | 0.99              | 0.97              | 0.80              | 1.14              | 0.90                | 1.31              | 1.14              | 1.12              |
| Na2O           | 3.33              | 3.69              | 3.65              | 3.65              | 3.98                | 3.55              | 2.92              | 3.75              |
| K2O            | 4.97              | 4.97              | 4.75              | 4.52              | 4.17                | 4.82              | 4.60              | 4.66              |
| TiO2           | 0.28              | 0.25              | 0.16              | 0.19              | 0.04                | 0.25              | 0.34              | 0.31              |
| P2O5           | 0.19              | 0.27              | 0.24              | 0.19              | 0.19                | 0.29              | 0.26              | 0.27              |
| MnO            | 0.03              | 0.05              | 0.04              | 0.07              | 0.03                | 0.03              | 0.05              | 0.05              |
| H2O            | 0.30              | 0.50              | 0.70              | 0.80              | 0.50                | 0.90              | 0.30              | 0.40              |
| Q              | 32.19             | 29.62             | 33.15             | 31.95             | 34.39               | 30.94             | 34.99             | 30.36             |
| OR             | 29.16             | 29.61             | 28.27             | 26.80             | 25.02               | 28.75             | 27.39             | 27.59             |
| AB             | 27.94             | 31.45             | 31.07             | 30.95             | 34.16               | 30.29             | 24.87             | 31.76             |
| AN             | 2.85              | 1.22              | 0.27              | 2.04              | 0.45                | 0.49              | 2.98              | 1.76              |
| C              | 2.94              | 2.56              | 2.69              | 2.82              | 2.31                | 3.49              | 3.37              | 2.37              |
| EN             | 2.45              | 2.43              | 2.00              | 2.85              | 2.27                | 3.29              | 2.86              | 2.79              |
| IL             | 0.06              | 0.11              | 0.09              | 0.15              | 0.07                | 0.06              | 0.11              | 0.11              |
| HM             | 1.74              | 2.18              | 1.78              | 1.89              | 0.88                | 1.79              | 2.54              | 2.38              |
| RU             | 0.24              | 0.20              | 0.12              | 0.11              | 0.01                | 0.22              | 0.29              | 0.25              |
| AP             | 0.44              | 0.63              | 0.56              | 0.44              | 0.45                | 0.68              | 0.61              | 0.63              |
| A/CNK          | 1.20              | 1.15              | 1.18              | 1.20              | 1.16                | 1.23              | 1.24              | 1.14              |
| TTDI           | 89.28             | 90.68             | 92.50             | 89.70             | 93.57               | 89.98             | 87.25             | 89.71             |
| Col Ind        | 4.24              | 4.72              | 3.87              | 4.89              | 3.22                | 5.15              | 5.50              | 5.28              |
| Ba             | 396               | 222               | 139               | 230               | 89                  | 254               | 288               | 240               |
| Rb             | 250               | 334               | 298               | 262               | 168                 | 331               | 272               | 299               |
| Sr             | 74                | 48                | 31                | 62                | 27                  | 56                | 65                | 56                |
| Zr             | 132               | 112               | 73                | 77                | 24                  | 99                | 146               | 116               |
| Nb             | 9                 | 17                | 12                | 11                | 5                   | 15                | 15                | 13                |
| V              | 15                | 9                 | 3                 | 9                 | 0                   | 16                | 20                | 19                |
| Y              | 18                | 23                | 20                | 23                | 10                  | 17                | 27                | 28                |
| Ga             | 25                | 25                | 24                | 20                | 19                  | 21                | 20                | 21                |
| Cu             | 0                 | 0                 | 0                 | 0                 | 4                   | 0                 | 0                 | 0                 |
| Zn             | 46                | 59                | 46                | 44                | 20                  | 78                | 56                | 58                |
| Hf             | 4                 | 4                 | 2                 | 2                 | 1                   | 1                 | 5                 | 4                 |
| Ta             | 1.1               | 2.5               | 1.9               | 1.6               | 1.0                 | 1.6               | 1.6               | 2.1               |
| Sc             | 3.4               | 3.8               | 2.8               | 4.0               | 0.6                 | 2.9               | 4.0               | 4.9               |
| La             | 32                | 25                | 12                | 14                | 3                   | 9                 | 25                | 25                |
| Th             | 17.0              | 15.0              | 7.7               | 7.3               | 1.2                 | 15.0              | 17.0              | 17.0              |
| U              | 4.0               | 5.4               | 4.0               | 2.8               | 5.1                 | 5.4               | 3.0               | 3.3               |
| Li             | 68                | 114               | 80                | 95                | 28                  | 182               | 128               | 41                |
| F              | 690               | 1000              | 820               | 660               | 245                 | 2150              | 1175              | 1145              |
| As             | 0.5               | 1.5               | 2.2               | 3.0               | 7.2                 | 352.0             | 0.8               | 1.6               |
| Sn             | 10                | 20                | 16                | 12                | 9                   | 20                | 10                | 5                 |
| W              | 1                 | 2                 | 1                 | 1                 | 3                   | 26                | 1                 | 1                 |

## NRP cont.

| SAMPLE UNIT                    | A09-2376<br>FGLMG | A09-2146-2<br>MLG | A09-2152-1<br>MLG | A09-2152-2<br>MLG | A16-1216-4<br>MLG | A16-1256<br>MLG | A16-1260-1<br>MLG | A16-1265<br>MLG |
|--------------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-----------------|-------------------|-----------------|
| SiO <sub>2</sub>               | 72.17             | 74.77             | 74.90             | 74.27             | 73.82             | 73.81           | 72.05             | 72.74           |
| Al <sub>2</sub> O <sub>3</sub> | 14.47             | 14.22             | 14.16             | 13.88             | 14.46             | 14.72           | 15.38             | 14.66           |
| Fe <sub>2</sub> O <sub>3</sub> | 2.14              | 1.38              | 1.33              | 1.79              | 1.18              | 1.13            | 0.95              | 1.19            |
| CaO                            | 0.67              | 0.21              | 0.26              | 0.31              | 0.31              | 0.32            | 0.40              | 0.22            |
| MgO                            | 1.25              | 0.69              | 0.66              | 0.84              | 0.70              | 0.71            | 0.72              | 0.70            |
| Na <sub>2</sub> O              | 4.21              | 3.72              | 3.49              | 3.21              | 3.55              | 3.97            | 4.86              | 3.57            |
| K <sub>2</sub> O               | 4.69              | 4.37              | 4.23              | 4.38              | 4.30              | 4.09            | 3.50              | 4.17            |
| TiO <sub>2</sub>               | 0.28              | 0.08              | 0.08              | 0.13              | 0.06              | 0.06            | 0.04              | 0.06            |
| P <sub>2</sub> O <sub>5</sub>  | 0.27              | 0.29              | 0.34              | 0.33              | 0.41              | 0.48            | 0.54              | 0.41            |
| MnO                            | 0.05              | 0.03              | 0.03              | 0.04              | 0.04              | 0.03            | 0.03              | 0.03            |
| H <sub>2</sub> O               | 0.56              | 0.71              | 0.82              | 0.70              | 0.60              | 0.20            | 0.67              | 0.70            |
| Q                              | 27.13             | 35.39             | 37.54             | 37.83             | 35.99             | 34.12           | 29.66             | 35.64           |
| OR                             | 27.69             | 25.87             | 25.10             | 26.09             | 25.68             | 24.28           | 20.96             | 25.15           |
| AB                             | 35.55             | 31.50             | 29.63             | 27.35             | 30.32             | 33.71           | 41.63             | 30.80           |
| AN                             | 1.55              | 0.00              | 0.00              | 0.00              | 0.00              | 0.00            | 0.00              | 0.00            |
| C                              | 1.89              | 3.37              | 3.85              | 3.88              | 4.00              | 3.77            | 3.64              | 4.35            |
| EN                             | 3.11              | 1.72              | 1.65              | 2.11              | 1.76              | 1.77            | 1.82              | 1.78            |
| IL                             | 0.11              | 0.06              | 0.06              | 0.09              | 0.09              | 0.06            | 0.06              | 0.07            |
| HM                             | 2.14              | 1.38              | 1.33              | 1.80              | 1.19              | 1.13            | 0.96              | 1.21            |
| RU                             | 0.22              | 0.05              | 0.05              | 0.09              | 0.02              | 0.03            | 0.01              | 0.03            |
| AP                             | 0.63              | 0.67              | 0.79              | 0.77              | 0.96              | 1.12            | 1.27              | 0.97            |
| A/CNK                          | 1.09              | 1.27              | 1.31              | 1.31              | 1.31              | 1.28            | 1.23              | 1.36            |
| TTDI                           | 90.36             | 92.75             | 92.27             | 91.27             | 91.99             | 92.11           | 92.25             | 91.59           |
| Col. Ind.                      | 5.35              | 3.16              | 3.05              | 4.00              | 3.04              | 2.97            | 2.84              | 3.06            |
| Ba                             | 291               | 27                | 34                | 80                | 19                | 15              | 77                | 23              |
| Rb                             | 347               | 754               | 677               | 691               | 765               | 896             | 845               | 866             |
| Sr                             | 58                | 11                | 16                | 23                | 14                | 16              | 28                | 20              |
| Zr                             | 127               | 44                | 42                | 76                | 39                | 39              | 26                | 43              |
| Nb                             | 13                | 27                | 22                | 22                | 28                | 28              | 34                | 29              |
| V                              | 13                | 0                 | 0                 | 5                 | 3                 | 4               | 0                 | 1               |
| Y                              | 29                | 38                | 37                | 41                | 26                | 25              | 39                | 27              |
| Ga                             | 20                | 28                | 24                | 24                | 30                | 32              | 30                | 26              |
| Cu                             | 0                 | 0                 | 0                 | 0                 | 0                 | 0               | 0                 | 0               |
| Zn                             | 60                | 69                | 55                | 69                | 77                | 87              | 64                | 74              |
| Hf                             | 4                 | 2                 | 2                 | 3                 | 1                 | 1               | 2                 | 1               |
| Ta                             | 23                | 7.0               | 6.6               | 5.7               | 1.1               | 1.1             | 14.0              | 8.7             |
| Sc                             | 4.2               | 2.2               | 2.4               | 2.7               | 1.7               | 1.8             | 2.2               | 1.7             |
| La                             | 25                | 5                 | 6                 | 12                | 3                 | 2               | 0                 | 3               |
| Th                             | 20.6              | 6.2               | 6.9               | 13.0              | 4.5               | 5.0             | 2.0               | 5.5             |
| U                              | 4.1               | 4.0               | 3.6               | 4.4               | 5.2               | 4.6             | 4.3               | 5.7             |
| Li                             | 71                | 324               | 375               | 419               | 417               | 502             | 336               | 497             |
| F                              | 1705              | 4200              | 4240              | 3965              | 3300              | 3650            | 4135              | 3700            |
| As                             | 1.5               | 0.9               | 0.9               | 2.5               | 1.9               | 2.1             | 0.7               | 1.4             |
| Sn                             | 8                 | 39                | 26                | 30                | 38                | 41              | 31                | 38              |
| W                              | 3                 | 11                | 9                 | 7                 | 19                | 8               | 8                 | 9               |

# WEST DALHOUSIE PLUTON (WDP)

| SAMPLE                         | A11-2239 | A11-2249 | A11-2259 | A11-2262-1 | A11-2291 | A11-2292 | A11-2293 | A11-3005 |
|--------------------------------|----------|----------|----------|------------|----------|----------|----------|----------|
| Rock Type                      | CGLMG    | CGLMG    | CGLMG    | FGLMG      | FGLMG    | FGLMG    | CGLMG    | CGLMG    |
| Major Elements (wt %)          |          |          |          |            |          |          |          |          |
| SiO <sub>2</sub>               | 73.01    | 72.62    | 73.34    | 72.89      | 74.75    | 73.33    | 74.28    | 74.19    |
| Al <sub>2</sub> O <sub>3</sub> | 14.02    | 14.55    | 14.13    | 14.82      | 14.47    | 14.05    | 13.97    | 13.67    |
| Fe <sub>2</sub> O <sub>3</sub> | 1.88     | 1.87     | 1.89     | 1.28       | 1.08     | 1.69     | 1.55     | 1.60     |
| CaO                            | 0.63     | 0.54     | 0.45     | 0.47       | 0.33     | 0.47     | 0.47     | 0.60     |
| MgO                            | 0.93     | 1.17     | 1.05     | 0.96       | 0.86     | 0.99     | 0.97     | 1.02     |
| Na <sub>2</sub> O              | 2.94     | 3.30     | 3.09     | 3.12       | 2.92     | 3.48     | 3.25     | 3.11     |
| K <sub>2</sub> O               | 4.97     | 5.00     | 4.97     | 4.90       | 4.28     | 4.63     | 4.75     | 4.72     |
| TiO <sub>2</sub>               | 0.29     | 0.23     | 0.21     | 0.16       | 0.11     | 0.22     | 0.16     | 0.24     |
| P <sub>2</sub> O <sub>5</sub>  | 0.25     | 0.18     | 0.14     | 0.28       | 0.27     | 0.24     | 0.17     | 0.23     |
| MnO                            | 0.04     | 0.04     | 0.04     | 0.03       | 0.03     | 0.04     | 0.05     | 0.04     |
| H <sub>2</sub> O               | 0.50     | 1.10     | 0.60     | 0.80       | 0.50     | 0.70     | 0.60     | 0.70     |
| Normative Mineralogy           |          |          |          |            |          |          |          |          |
| Q                              | 35.21    | 32.04    | 34.43    | 34.70      | 40.53    | 33.84    | 35.34    | 36.07    |
| OR                             | 29.71    | 29.72    | 29.60    | 29.30      | 25.43    | 27.62    | 28.20    | 28.08    |
| AB                             | 25.14    | 28.06    | 26.33    | 26.69      | 24.93    | 29.70    | 27.60    | 26.47    |
| AN                             | 1.50     | 1.51     | 1.33     | 0.50       | 0.00     | 0.77     | 1.22     | 1.48     |
| C                              | 3.29     | 3.17     | 3.20     | 4.24       | 5.10     | 3.06     | 3.04     | 2.92     |
| EN                             | 2.34     | 2.93     | 2.63     | 2.42       | 2.16     | 2.49     | 2.42     | 2.55     |
| IL                             | 0.09     | 0.09     | 0.09     | 0.06       | 0.06     | 0.09     | 0.11     | 0.09     |
| HM                             | 1.90     | 1.88     | 1.90     | 1.29       | 1.09     | 1.70     | 1.56     | 1.61     |
| RU                             | 0.25     | 0.19     | 0.17     | 0.13       | 0.08     | 0.18     | 0.10     | 0.20     |
| AP                             | 0.59     | 0.42     | 0.33     | 0.66       | 0.63     | 0.56     | 0.40     | 0.54     |
| A/CNK                          | 1.23     | 1.23     | 1.25     | 1.31       | 1.44     | 1.21     | 1.23     | 1.21     |
| TTDI                           | 90.05    | 89.82    | 90.36    | 90.69      | 90.88    | 91.16    | 91.15    | 90.62    |
| Col. Ind.                      | 4.33     | 4.89     | 4.62     | 3.78       | 3.32     | 4.28     | 4.09     | 4.25     |
| Trace Elements (ppm*)          |          |          |          |            |          |          |          |          |
| Ba                             | 355      | 391      | 438      | 271        | 74       | 128      | 202      | 260      |
| Rb                             | 239      | 216      | 221      | 258        | 329      | 290      | 258      | 256      |
| Sr                             | 58       | 72       | 73       | 63         | 17       | 26       | 43       | 47       |
| Zr                             | 120      | 95       | 86       | 56         | 27       | 84       | 61       | 90       |
| Nb                             | 14       | 10       | 10       | 11         | 16       | 14       | 8        | 12       |
| V                              | 6        | 12       | 15       | 0          | 5        | 11       | 11       | 9        |
| Y                              | 19       | 20       | 23       | 19         | 20       | 22       | 23       | 18       |
| Ga                             | 17       | 16       | 15       | 17         | 21       | 18       | 15       | 17       |
| Cu                             | 0        | 0        | 0        | 0          | 0        | 0        | 0        | 0        |
| Zn                             | 52       | 40       | 36       | 52         | 31       | 55       | 30       | 55       |
| Hf                             | 3        | 3        | 2        | 0          | 0        | 2        | 2        | 3        |
| Ta                             | 1.6      | 1.5      | 1.7      | 2.0        | 5.4      | 1.9      | 1.8      | 2.0      |
| Sc                             | 2.7      | 2.8      | 3.4      | 1.9        | 1.8      | 2.5      | 3.2      | 2.0      |
| La                             | 32       | 20       | 20       | 11         | 7        | 21       | 10       | 23       |
| Th                             | 22.2     | 12.0     | 10.0     | 5.3        | 5.1      | 16.0     | 5.7      | 17.0     |
| U                              | 4.5      | 4.4      | 5.1      | 7.7        | 14.0     | 4.5      | 4.2      | 3.7      |
| Li                             | 89       | 36       | 71       | 125        | 51       | 117      | 54       | 90       |
| F                              | 670      | 345      | 383      | 316        | 590      | 756      | 393      | 785      |
| As                             | 1.7      | 2.1      | 8.4      | 4.6        | 18.0     | 1.9      | 10.0     | 4.0      |
| Sn                             | 6        | 0        | 9        | 11         | 16       | 7        | 11       | 2        |
| W                              | 0        | 0        | 3        | 2          | 6        | 0        | 4        | 2        |

## WDP cont.

| SAMPLE<br>Rock Type            | A11-3013<br>CGLMG | A11-3015<br>CGLMG | A14-0007<br>CGLMG | A14-0007-1<br>CGLMG | A15-0115-4<br>CGLMG | A15-0115-5<br>CGLMG |
|--------------------------------|-------------------|-------------------|-------------------|---------------------|---------------------|---------------------|
| SiO <sub>2</sub>               | 72.06             | 73.31             | 70.32             | 71.55               | 71.32               | 70.87               |
| Al <sub>2</sub> O <sub>3</sub> | 14.94             | 13.94             | 15.59             | 14.89               | 14.63               | 15.09               |
| Fe <sub>2</sub> O <sub>3</sub> | 1.83              | 2.13              | 2.37              | 2.44                | 2.22                | 2.13                |
| CaO                            | 0.69              | 0.70              | 0.88              | 0.79                | 0.74                | 0.69                |
| MgO                            | 1.00              | 0.94              | 1.28              | 1.27                | 1.04                | 1.06                |
| Na <sub>2</sub> O              | 2.95              | 3.00              | 3.09              | 2.89                | 3.46                | 3.57                |
| K <sub>2</sub> O               | 5.07              | 4.64              | 5.49              | 5.10                | 4.88                | 5.09                |
| TiO <sub>2</sub>               | 0.23              | 0.32              | 0.34              | 0.35                | 0.31                | 0.30                |
| P <sub>2</sub> O <sub>5</sub>  | 0.23              | 0.24              | 0.21              | 0.20                | 0.21                | 0.21                |
| MnO                            | 0.04              | 0.04              | 0.05              | 0.04                | 0.05                | 0.05                |
| H <sub>2</sub> O               | 0.50              | 0.40              | 0.70              | 0.70                | 0.48                | 0.49                |
| Q                              | 33.46             | 36.13             | 28.22             | 32.34               | 30.30               | 28.41               |
| OR                             | 30.26             | 27.65             | 32.60             | 30.31               | 29.20               | 30.39               |
| AB                             | 25.19             | 25.57             | 26.24             | 24.57               | 29.61               | 30.49               |
| AN                             | 1.94              | 1.92              | 3.00              | 2.62                | 2.32                | 2.07                |
| C                              | 3.93              | 3.31              | 3.48              | 3.67                | 2.84                | 2.98                |
| EN                             | 2.51              | 2.36              | 3.20              | 3.18                | 2.62                | 2.66                |
| IL                             | 0.09              | 0.09              | 0.11              | 0.09                | 0.11                | 0.11                |
| HM                             | 1.90              | 2.15              | 2.38              | 2.45                | 2.25                | 2.15                |
| RU                             | 0.19              | 0.28              | 0.28              | 0.31                | 0.26                | 0.25                |
| AP                             | 0.54              | 0.56              | 0.49              | 0.47                | 0.49                | 0.49                |
| A/CNK                          | 1.29              | 1.24              | 1.23              | 1.27                | 1.19                | 1.19                |
| TTDI                           | 88.92             | 89.35             | 87.06             | 87.22               | 89.11               | 89.29               |
| Col. Ind.                      | 4.50              | 4.59              | 5.69              | 5.72                | 4.97                | 4.92                |
| Ba                             | 288               | 355               | 407               | 467                 | 377                 | 379                 |
| Rb                             | 266               | 267               | 258               | 245                 | 253                 | 278                 |
| Sr                             | 62                | 61                | 94                | 87                  | 73                  | 72                  |
| Zr                             | 90                | 122               | 132               | 143                 | 124                 | 119                 |
| Nb                             | 13                | 13                | 14                | 14                  | 13                  | 14                  |
| V                              | 8                 | 14                | 17                | 15                  | 15                  | 14                  |
| Y                              | 22                | 20                | 23                | 20                  | 24                  | 24                  |
| Ga                             | 18                | 18                | 21                | 19                  | 19                  | 20                  |
| Cu                             | 0                 | 0                 | 0                 | 0                   | 0                   | 0                   |
| Zn                             | 58                | 63                | 59                | 60                  | 55                  | 59                  |
| Hf                             | 2                 | 3                 | 5                 | 6                   | 4                   | 4                   |
| Ta                             | 1.9               | 2.0               | 1.3               | 1.4                 | 1.6                 | 1.7                 |
| Sc                             | 2.1               | 2.6               | 4.0               | 4.3                 | 4.2                 | 3.9                 |
| La                             | 24                | 33                | 34                | 40                  | 34                  | 32                  |
| Th                             | 15.0              | 24.9              | 19.0              | 23.2                | 20.0                | 18.0                |
| U                              | 5.8               | 4.6               | 4.2               | 4.5                 | 6.0                 | 8.2                 |
| Li                             | 107               | 119               | 70                | 65                  | 91                  | 86                  |
| F                              | 780               | 958               | 375               | 618                 | 740                 | 970                 |
| As                             | 2.6               | 2.7               | 4.3               | 3.5                 | 5.9                 | 17.0                |
| Sn                             | 7                 | 10                | 4                 | 3                   | 0                   | 9                   |
| W                              | 1                 | 1                 | 0                 | 2                   | 2                   | 0                   |



# APPENDIX B

## List of Abbreviations

| Minerals |                    | Alteration                        |                                                        |
|----------|--------------------|-----------------------------------|--------------------------------------------------------|
| am       | amethyst           | Alb                               | albitization                                           |
| ap       | apatite            | Bio                               | biotization                                            |
| as       | arsenopyrite       | Car                               | carbonatization                                        |
| au       | autunite           | Chl                               | chloritization                                         |
| az       | azurite            | Gre                               | greisenization                                         |
| ba       | barite             | Haa                               | high-alumina alteration (e.g. andalusite, sillimanite) |
| be       | beryl              | Hem                               | hematization                                           |
| bo       | bornite            | Kao                               | kaolinization                                          |
| ca       | calcite            | Lim                               | limonitization                                         |
| cc       | chalcocite         | Pot                               | potassic (e.g. K-feldspathization)                     |
| cp       | chalcopyrite       | Sau                               | saussuritization                                       |
| ch       | chlorite           | Ser                               | sericitization                                         |
| cd       | cordierite         | Sil                               | silicification                                         |
| cy       | chrysocolla        |                                   |                                                        |
| fl       | fluorite           |                                   |                                                        |
| gn       | galena             |                                   |                                                        |
| gp       | graphite           |                                   |                                                        |
| gr       | garnet             |                                   |                                                        |
| he       | hematite           |                                   |                                                        |
| ka       | kaolinite          |                                   |                                                        |
| ks       | cassiterite        |                                   |                                                        |
| ma       | malachite          |                                   |                                                        |
| mn       | manganese minerals |                                   |                                                        |
| mo       | molybdenite        |                                   |                                                        |
| mr       | marcasite          |                                   |                                                        |
| mu       | muscovite          |                                   |                                                        |
| pi       | pitchblende        |                                   |                                                        |
| po       | pyrrhotite         |                                   |                                                        |
| py       | pyrite             |                                   |                                                        |
| qz       | quartz             |                                   |                                                        |
| se       | sericite           |                                   |                                                        |
| sh       | scheelite          |                                   |                                                        |
| sn       | stannite           |                                   |                                                        |
| sp       | sphalerite         |                                   |                                                        |
| st       | stibnite           |                                   |                                                        |
| to       | torbernite         |                                   |                                                        |
| tp       | topaz              |                                   |                                                        |
| tr       | tourmaline         |                                   |                                                        |
| wo       | wolframite         |                                   |                                                        |
|          |                    | Host Rock Types / Formation Names |                                                        |
|          |                    | APLI                              | Aplite                                                 |
|          |                    | BGD                               | Biotite granodiorite                                   |
|          |                    | BMG                               | Biotite monzogranite                                   |
|          |                    | CGLMG                             | Coarse-grained leucomonzogranite                       |
|          |                    | COG                               | Goldenville Formation                                  |
|          |                    | COH                               | Halifax Formation                                      |
|          |                    | DT                                | Torbrook Formation                                     |
|          |                    | FGLMG                             | Fine-grained leucomonzogranite                         |
|          |                    | MBMG                              | Muscovite-biotite monzogranite                         |
|          |                    | MLG                               | Muscovite leucogranite                                 |
|          |                    | MP                                | Mafic porphyry                                         |
|          |                    | OSW                               | White Rock Formation                                   |
|          |                    | PEGM                              | Pegmatite                                              |
|          |                    | SK                                | Kentville Formation                                    |
|          |                    | SYEN                              | Syenogranite                                           |
|          |                    | TNM                               | North Mountain Formation                               |

| Name, Map Sheet and Number     | Northing                 | Easting          | Type             | Ore Minerals<br>(elements in brackets) | Gangue     | Alteration    | Host<br>Rock     | <i>Qz</i><br>Veins   | Fract/<br>Shear | Comments                                                                                                                                                          |
|--------------------------------|--------------------------|------------------|------------------|----------------------------------------|------------|---------------|------------------|----------------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sandwich Peak<br>11D-12        | 491750                   | 456260           | Graben           | ss, py, sp                             | qt         | ma-Grt        | CGJAG            | 185-66 W<br>175-70 W |                 | Vein widths, 5-10 cm. Abundant gr. garnet<br>system exposed for 200m along the road.<br>Maximum wt%: 7.6% As, 559 ppb<br>Au.                                      |
| Thief Peak<br>11D-12           | 4927760                  | 451835           | Graben           | ss                                     | qt         | Grt           | ABMG             | 128-78 N             |                 | Vein widths, 3-1.5m. Minor<br>greenstonation along the 137-96 W joint.                                                                                            |
| Head of Strad Bay<br>11D-12    | 491180                   | 476550           | Pegmatite        | ss, sp, ma, fs                         | qt, fl, fs | ss-Grt        | FOLMG<br>(FLOMG) |                      |                 | Mineralization occurs in pegmatite pods.<br>Majority of garnets attain maximum width<br>of 15cm along dominant joint set<br>(143-90). Close to contact with DCGH. |
| Governor Lake<br>11D-12        | 4944070                  | 443070           | Breccia          | py, ma                                 | am, qt     | Si, Hsm, Cr   | CGJAG            |                      | 134-85          | Quartz breccia along Herring Creek fault.<br>Maximum wt% in grab sample: 811 ppb<br>Au, 340 ppm Zn.                                                               |
| Head of Prospect Bay<br>11D-12 | 4930870                  | 459160           | Graben           | sp, fs, ss, ma                         | qt, fs     | Grt           | ABMG             | 145-83 W             |                 | Vein widths, 0-1 cm. Close to contact<br>with DCGH.                                                                                                               |
| Upper Tantalum<br>11D-12       | 4946760                  | 431270           | Vein             | py, py, sp, fl                         | qt         | ma-Grt<br>Hsm | FOLMG            |                      |                 | Close to contact with DCGH.                                                                                                                                       |
| Tantalum<br>11D-12             | 4950960                  | 430160           | Graben           | py, ss                                 | qt         | Grt, Hsm      | CGJAG            | 137-90               |                 | Vein widths, 0-1.5m spread<br>approximately 1m apart.                                                                                                             |
| Sandy Lake<br>11D-12           | 4952280                  | 427560           | Vein?            | ss                                     | qt         | ma-Grt        | BMG              | 147-86<br>NW         |                 |                                                                                                                                                                   |
| West of Island Lake<br>11D-12  | 4952400                  | 424950           | Graben           | ss, py, fs                             | qt         | ma-Grt        | FOLMG            | 140-60<br>N          |                 | Vein widths, 0-1.4m, parallel to one<br>another. Same vein approach 80-100%<br>As and minor Fe.                                                                   |
| Near Ingers River<br>11D-12    | 1) 4948760<br>2) 4948330 | 424320<br>422980 | Graben<br>Graben | py, sp, fs, fs, ma                     | qt         | Hsm, Grt      | BMG              | 150-80 W<br>147-76 E |                 | Vein widths, 0-15cm.                                                                                                                                              |
| East of Packer Lake<br>11D-12  | 4925510                  | 429540           | Pegmatite        | fs                                     | qt, fs, fl | ma-Grt        | BMG              |                      |                 | No hydrothermal zoning recognized.                                                                                                                                |

| Name, Map Sheet and Number          | Northing                      | Easting                    | Type                 | Ore Minerals<br>(elements in brackets)      | Gangue      | Alteration                                   | Host<br>Rock | Qz<br>Veins | Fract/<br>Shear | Comments                                                                                                                                                                                                                 |
|-------------------------------------|-------------------------------|----------------------------|----------------------|---------------------------------------------|-------------|----------------------------------------------|--------------|-------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Christie Lake Showings<br>11D/13    | 4961870<br>4961880<br>4961740 | 425520<br>426480<br>426580 | Vein<br>Vein<br>Vein | ws, sh, qp, ms                              | qtz         | Grn                                          | CGLMG        | 110/72 N3   |                 | 1 and 2 are the smaller deposits. Vein widths < 2.5m; with 9m crystals < 7m. Assays: 3% WO3 and trace Cu, Mo, Au (525 ppb)                                                                                               |
| M.E.N. U-Cu Showing<br>11D/13       | 4964140                       | 425780                     | Vein                 | ls, ms, qp, py                              |             | Hem, Kfs,<br>Hss                             | CGLMG        |             | NE<br>Trending  | Anthophyllite, sillimanite, heterophane spinel, orthoclase, garnet, biotite and tremolite are the result of intense high-temperature hydrothermal alteration. Assays: 25.4 g/t andalusite, with crystal lengths < 1.25m. |
| Bates Lake Showing<br>11D/13        | 4955480                       | 422640                     | Ground               | qp, ws, py                                  | qtz         | ms-Grn<br>Hem, Sss                           | FGLMG        |             |                 | Porphyry deposit.                                                                                                                                                                                                        |
| Little Toboatic Lake<br>21A/3       | 4952300                       | 314050                     | Ground               | gn, sp, fs, qp, ss, py<br>(As)              | qtz         | Sil                                          | COG          |             |                 | This occurrence extends for 2km. Assays up to 4.9% Pb, Zn and 2% Ba.                                                                                                                                                     |
| Pug Lake<br>21A/3                   | 4897900                       | 308200                     | Vein                 | py, ss                                      | qtz, tr?    |                                              | FGLMG        |             |                 | In sharp contact with DCuMDE.                                                                                                                                                                                            |
| East Kentville Tin Deposit<br>21A/4 | 4886800                       | 285430                     | Ground               | ks, qp, ap, py, ps, cl,<br>ws, ms, gn       |             | ms-Grn                                       | MLG + COG    |             |                 | Initial reserves, 50m tons, grading 165% Sn.                                                                                                                                                                             |
| Duck Pond Deposit<br>21A/4          | 4886770                       | 283080                     | Vein                 | ks, py, qp, ps, ss, qp                      | qtz, sh     | Sil, Sss, Chl,<br>Hem,<br>Alkali,<br>Argill. | COG          |             |                 | Close to contact with DCIGES. Probable and inferred reserves total 3.6m tons of 1269% Sn.                                                                                                                                |
| Ives Ridge<br>21A/4                 | 4885790                       | 282740                     | Vein                 | py, qp, ps, qp, ms,<br>ss, ms (Bq)          | qtz, qp, fl | Alb                                          | CGLMG        |             |                 | Showings and brecciation occur in zone of 50m to 2m wide.                                                                                                                                                                |
| Goodness Meadow Brook<br>21A/4      | 4881790<br>4882960            | 277820<br>279100           | ???                  | py, ps, ss, qp                              |             | Chl                                          | COG          |             |                 |                                                                                                                                                                                                                          |
| Fanning Lake Prospect<br>21A/4      | 4878240                       | 266040                     | Vein                 | py, ss, qp, ps, qp<br>(Chl, Alkali, Bq, Tr) | qtz         | Sil, Sss, Chl,<br>Hem                        | COG          |             |                 |                                                                                                                                                                                                                          |

| Name, Map Sheet and Number  | Northing | Easting | Type    | Ore Minerals<br>(elements in brackets) | Gangue                           | Alteration       | Host<br>Rock | Qtz<br>Veins | Fract/<br>Shear | Comments                                                       |
|-----------------------------|----------|---------|---------|----------------------------------------|----------------------------------|------------------|--------------|--------------|-----------------|----------------------------------------------------------------|
| Kromt Sme Lake<br>21A/4     | 4875960  | 271600  | Crustal | gn, sp, ss, sh, qp, zn,<br>Fe          | qtz, ox, fl                      | Ham. Grt         | COG          |              | SW<br>trailing  |                                                                |
| Wentworth Lake<br>21A/4     | 4895940  | 265040  | Vein    | py, sp, pr                             | qtz, ox                          |                  | COG          |              |                 |                                                                |
| Pearl Lake<br>21A/4         | 4879060  | 274300  | Vein    | py, sp, ss, ks, ap,<br>Native Bi       |                                  | Sil, Cl          | COG          |              |                 |                                                                |
| Bread Lake<br>21A/4         | 4876100  | 259260  | Pegmat  | sp, bi, ur, ap, ks<br>(Ta, Cs)         | qtz, mnt,<br>Fe-dpsr,<br>biotite |                  | OSW          |              |                 | Only spodumene bearing pegmatite in<br>N.A.                    |
| Gillford Lake<br>21A/4      | 4890960  | 269730  | Vein    | ks, py, sp                             | qtz, fl                          |                  | CGLMG        |              |                 |                                                                |
| Tusket<br>21A/4             | 4877369  | 274060  | Py      | py, sp, bi, ss, mnt                    |                                  |                  | COG          |              |                 |                                                                |
| Kempville<br>21A/4          | 4881550  | 272100  | Vein    | (An) py, ss, pr                        | qtz                              |                  | COG          |              | Y               |                                                                |
| Carlton District<br>21A/4   | 4876420  | 264500  | Vein    | (An) an, py, zn, ss, qp                | qtz                              |                  | COG          |              |                 | Vein widths < 10-20 cm and ranging up<br>to < 90 cm in length. |
| Shedoff Lake<br>21A/5       | 4928700  | 279920  | Breccia | py, sh, qp, bi, he<br>(U, Cs)          | qtz                              | Sil, Car,<br>Ham | SK           |              |                 | Uranium levels (< 7 ppm) encountered<br>during soil survey.    |
| Sandwich River<br>21A/5     | 4916290  | 272680  | Vein    | py, pr                                 | qtz                              |                  | OSW          |              |                 | Vein not located during the present<br>survey.                 |
| Whitburn (Azt)<br>21A/6 & 7 | 4908280  | 334540  | Vein    | (Azt)                                  | qtz                              |                  | COG          |              |                 |                                                                |
| Wye Colonia<br>21A/6 & 7    | 4913600  | 327280  | Vein    | (Azt)                                  | qtz                              |                  | COG          |              |                 |                                                                |

| Name, Map Sheet and Number           | Northings                                                                                          | Eastings                                                 | Type                                               | Ore Minerals<br>(elements in brackets)                                      | Gangue                     | Alteration             | Host<br>Rock | Qtz<br>Veins | Fract./<br>Shear | Comments                                                    |
|--------------------------------------|----------------------------------------------------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------------------------------|----------------------------|------------------------|--------------|--------------|------------------|-------------------------------------------------------------|
| Westfield Area<br>21A/6 & 7          | Aj<br>4919380<br>Bj<br>4920740<br>Cj<br>4918640<br>Dj<br>4919420<br>Ej<br>4918390<br>Fj<br>4918730 | 341180<br>341185<br>341880<br>340240<br>341310<br>341420 | Grasson<br>Vein<br>Grasson<br>Vein<br>Brecker/Vein | py, ss, sp, gr<br>mn<br>ca, sh<br>py, ss, sh<br>Cln, Wj<br>(As, Sb, Sn, Pb) | qt<br>qt<br>qt<br>qt<br>qt | Gre. Alb<br>Alb<br>Gre |              |              |                  | Vein width 1.2m<br>Vein width 0.22m                         |
| Kedge Ledge New Grafton<br>21A/6 & 7 | 4918355                                                                                            | 322190                                                   |                                                    | py, pt, ap                                                                  |                            |                        |              |              |                  |                                                             |
| Harmony Mills<br>21A/6 & 7           | 4917580                                                                                            | 334790                                                   | Vein                                               | sh                                                                          | qt                         |                        |              |              |                  | Vein width 4-6 inches. Unable to locate during expedition.  |
| Caledonia Area<br>21A/6 & 7          | 3aj<br>4913500<br>3bj<br>4913000<br>3cj<br>4912500                                                 | 337650<br>338520<br>338960                               | Vein<br>Brecker                                    | sh, ep, sp, ks, py                                                          | ca, qt                     |                        |              |              |                  | Three distinct veins were recognized.                       |
| Moosehide Lake<br>21A/6 & 7          | 7aj<br>4909580<br>7bj<br>4907680                                                                   | 301880<br>304980                                         | Brecker<br>Brecker                                 | to, an, py                                                                  |                            | Sil. Hem               |              |              |                  |                                                             |
| Tupper Lake<br>21A/6 & 7             | 8aj<br>4926220<br>8bj<br>4923870                                                                   | 340390<br>340550                                         | Vein<br>Vein                                       | wt                                                                          |                            |                        | APLJ         |              |                  | Vein width 2mm                                              |
| Kiddy Prospect<br>21A/9              | 4952240                                                                                            | 381400                                                   |                                                    |                                                                             |                            |                        |              |              |                  | Refer to O'Grady et al '82                                  |
| Leville<br>21A/9                     | 4955880                                                                                            | 388440                                                   | Pegon                                              | ap, w-s                                                                     | qt                         |                        | MLG          |              |                  |                                                             |
| Queensland<br>21A/9                  | 4943780                                                                                            | 419320                                                   | Vein                                               | ss, ks, py                                                                  | qt                         | Hem                    | FGLMG        |              |                  | Vein width < 1 cm                                           |
| Fox Point<br>21A/9                   | 4939100                                                                                            | 416200                                                   | Grasson                                            | ep, sp, as                                                                  | qt                         | mn Geo                 | MLG          |              |                  | Occurrence is 1.5m wide, grasson banded, sheared qtz veins. |

| Name, Map Sheet and Number           | Northing                   | Easting                                             | Type                                           | Ore Minerals<br>(elements in brackets) | Gangue                        | Alteration | Host<br>Rock                     | Qtz<br>Veins                           | Fract/<br>Shear                                                  | Comments                                                           |
|--------------------------------------|----------------------------|-----------------------------------------------------|------------------------------------------------|----------------------------------------|-------------------------------|------------|----------------------------------|----------------------------------------|------------------------------------------------------------------|--------------------------------------------------------------------|
| Bozeman Lake<br>21A/9                | 1)<br>2)<br>3)<br>4)<br>5) | 4943700<br>4943130<br>4942900<br>4939600<br>4937810 | 299560<br>398780<br>396440<br>395620<br>403720 | Gneiss &<br>Veins                      | (Cu, Zn, As,<br>Sn, W)        | qp, fl     | Horn. Ser.,<br>Alb., Pot,<br>Sil | COH<br>FGLMG<br>MRMG<br>COLMG<br>FGLMG |                                                                  | A large high value cDc/TH anomaly is<br>coincident with this area. |
| Long Lake<br>21A/9                   |                            | 4939440                                             | 391430                                         | Pgm &<br>Gneiss                        | (Mo, Cu, Zn, W,<br>Bi, Sn)    | qr         | ma Grc., Alb.,<br>Pot            | FGLMG                                  |                                                                  |                                                                    |
| Timber Lake<br>21A/9                 |                            | 4947845                                             | 405930                                         | Gneiss                                 | py                            | qr, fl     | ma Grc.                          | FGLMG                                  |                                                                  |                                                                    |
| Morley's Pegmatite Prospect<br>21A/9 |                            | 4954920                                             | 383700                                         | Pegm.                                  |                               |            |                                  |                                        |                                                                  | Refer to O'Reilly et al. (1982)                                    |
| Alton<br>21A/10                      |                            | 4953120                                             | 357580                                         | Gneiss                                 | sp, ch, ma, ka?               | qr, fl     |                                  | FGLMG                                  |                                                                  | Vein width < 20cm. Close to contact<br>with BGP.                   |
| Stanburn<br>21A/10                   |                            | 4942100                                             | 361550                                         | Vein                                   | (Au) sil                      | qr         |                                  | COG, BMG                               |                                                                  | As created with the BMG                                            |
| New Germany<br>21A/10                |                            | 4933740                                             | 354730                                         |                                        |                               |            |                                  | COG                                    |                                                                  | Not well documented. On the COG /<br>COH contact.                  |
| Reeves Tin Mine<br>21A/10            |                            | 4953800                                             | 379920                                         | Pegm.                                  | (Sn, W, La, Ta, U, Bi,<br>Ag) | fl         |                                  | MLG                                    |                                                                  | Close to contact with the DChmPL                                   |
| Lake Runge<br>21A/10                 |                            | 4955650                                             | 389850                                         |                                        | (Sn, W, Cu, Au)               | fl         |                                  | FGLMG                                  |                                                                  | Close to the contact with BMG                                      |
| East Dellbrone (U)<br>21A/10         |                            | 4959430                                             | 357100                                         |                                        | ma, to                        |            | Horn. Kaa                        | FGLMG                                  | No<br>trending,<br>sharply<br>spaced. Fract<br>and shear<br>Zone |                                                                    |
| Nevard Lake<br>21A/10                |                            | 4948000                                             | 380690                                         | Pegm.                                  | (Sn, W)                       |            |                                  | COLMG                                  |                                                                  | Area not verified by this study.                                   |



| Name, Map Sheet and Number        | Northing                     | Easting          | Type    | Ore Minerals<br>(elements in brackets) | Gangue | Alteration | Host<br>Rock   | Qz<br>Veins    | Fract/<br>Shear | Comments                                             |
|-----------------------------------|------------------------------|------------------|---------|----------------------------------------|--------|------------|----------------|----------------|-----------------|------------------------------------------------------|
| Black Duck Lake<br>21A/10         | 495020                       | 363190           | Vein    | ma (Fe)                                | qt     |            | FGLMG          |                |                 | Vein width 32 cm - close to the contact with the COG |
| Caribou Lake<br>21A/10            | 9)<br>4932140<br>10) 4932390 | 376180<br>376880 | Greisen | sp, mo (Bi)                            |        |            | SYEN           |                |                 |                                                      |
| Hemford<br>21A/10                 | 4930400                      | 358990           | Vein    | (Au)                                   | qt     |            | COH            |                |                 |                                                      |
| Lake Torment<br>21A/10            | 4951850<br>4952360           | 361380<br>363040 |         | ss, sp, fs, ac                         | qt     |            | COG            |                |                 | On contact of COG - FGLMG                            |
| Upper New Cornwall<br>21A/10      | 13)<br>4932670<br>14)        | 374540<br>374420 | Greisen | py, ss, sp, op<br>(Au, W, Bi)          |        |            | MBMG           | NW<br>trending |                 | Close to the contact with COG                        |
| East Dalhousie (No)<br>21A/10     | 15)<br>4951860<br>17)        | 365060<br>360600 | Greisen | (Sn)                                   | qt     |            | FGLMG          | NW<br>trending |                 | Close to contact with the COG                        |
| Indian Brook<br>21A/10            | 4937330                      | 365620           |         |                                        |        |            | COH            |                |                 | Not well documented                                  |
| Upper New Cornwall (Au)<br>21A/10 | 4928700                      | 376150           |         | (Au)                                   |        |            | COG            |                |                 | Not well documented                                  |
| Whale Lake<br>21A/10              | 4933790                      | 380790           | Greisen | sp, fs, wo, ss, py                     | qt     |            | MBMG           | NW<br>trending |                 | Vein width < 2 - 4 cm. Close to contact with DCmNR   |
| Saturday Lake<br>21A/10           | 4948720                      | 348180           | Vein    | ma                                     | qt     |            | MP             |                |                 | Close to contact with COG                            |
| Faulkland Ridge<br>21A/10         | 4945290                      | 353700           | Greisen | py, sp, mo                             | fl     |            | BMG            |                |                 | Vein width < 20 cm. Close to contact with the COG    |
| Tommy Lake<br>21A/10              | 4938920                      | 342080           | Greisen | mo, ss, sp, py                         |        |            | FGLMG<br>CGLMG |                |                 |                                                      |
| Lamba Lake<br>21A/11              | 4950200                      | 303860           | Vein    | (Al, Cu, Zn, Ag)                       | sp     | Heav. Cu   | DT             |                | weak            |                                                      |

| Name, Map Sheet and Number                                                                | Northing                                                       | Easting                                                  | Type   | Ore Minerals<br>(elements in brackets) | Gangue   | Alteration | Host<br>Rock                              | Oz<br>Value | Fract:<br>Shear    | Comments                                                                                            |
|-------------------------------------------------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------|--------|----------------------------------------|----------|------------|-------------------------------------------|-------------|--------------------|-----------------------------------------------------------------------------------------------------|
| Harcott Lake<br>21A/11                                                                    | 4951940                                                        | 327230                                                   | Vein   | py, sp                                 | qt       |            | MBMG                                      |             |                    | 10 x 25m zone of quartz stockwork.                                                                  |
| Hudson Lake<br>21A/11                                                                     | 4943920                                                        | 322100                                                   | Till   | sh                                     | qt       |            | BMG                                       |             |                    |                                                                                                     |
| Lindsey showing<br>21A/12                                                                 | 4919940                                                        | 283200                                                   | Vein   | as, py, po, st                         | qt       | Car        | COH                                       |             |                    |                                                                                                     |
| Digby Neck Showing<br>21A/12                                                              | 4952820                                                        | 279060                                                   | ??     | Nature Cu, ch, ma                      |          |            | TNM                                       |             |                    | Found within amphibolites of the<br>volcanic and sedimentary rocks to the east.                     |
| Juggins Bridge Showing<br>21A/12                                                          | 4941520                                                        | 281800                                                   | Vein   | (Au)<br>py, as, sh                     | qt       |            | COH                                       |             |                    | Gold grades up to 4.5 oz./ton.                                                                      |
| North of Batholite<br>Fe Deposits<br>21A/12<br>(Milbury) 10<br>(Milton) 10<br>(Potter) 10 | 4548320<br>4538810<br>4535180<br>4542590<br>4543420<br>4544340 | 260450<br>273910<br>274800<br>290800<br>295110<br>296440 |        | br, limonite<br>Fe<br>Fe<br>Fe<br>Fe   | qt, Fels |            | TNM<br>OSW<br>COG<br>OSW / SK<br>DT<br>DT |             |                    |                                                                                                     |
| Victoria Beach<br>21A/12                                                                  | 4950340                                                        | 281800                                                   |        | (V)                                    |          |            | TNM                                       |             |                    |                                                                                                     |
| Bartons Brook<br>21A/14                                                                   | 4967320                                                        | 330500                                                   | Gneiss | py, sp, bi                             |          | Gre, Bas   | OSW                                       |             |                    | Both boulders found had abundant<br>magnetite nodules. An unidentified silver<br>mineral was found. |
| Whitman Brook<br>21A/14                                                                   | 4968700                                                        | 331400                                                   | Gneiss | ma, as, w, sh                          | qt       | Hem, Gre   | FGLMG                                     |             |                    | Close to contact with COH.                                                                          |
| Nelson Quarry<br>21A/14                                                                   | 4979920                                                        | 334960                                                   | Vein   | ma, ap                                 | qt       |            | GD                                        | 112.80 N    | Vein width<br>< 2m |                                                                                                     |
| Inglesville<br>21A/14                                                                     | 4969410                                                        | 337250                                                   |        | (Fe)                                   |          |            | DT                                        |             |                    | Mineralized but traced for over 3.50m                                                               |

| Name, Map Sheet and Number       | Northing                                                            | Eastng                                         | Type                                                | Ore Minerals<br>(elements in brackets)                             | Gangue                                 | Alteration                                     | Host<br>Rock                       | Qtz<br>Veins                                 | Fract/<br>Shear       | Comments                                                                                             |
|----------------------------------|---------------------------------------------------------------------|------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------------|----------------------------------------|------------------------------------------------|------------------------------------|----------------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------|
| Nichols River<br>21A/14          | 4974870                                                             | 330990                                         |                                                     | (lt)<br>py, ps, sp                                                 |                                        |                                                | OSW                                |                                              | Y                     |                                                                                                      |
| Nichols Tributary Area<br>21A/14 | 4972790<br>4972670<br>4972640<br>4972490<br>4971960                 | 338780<br>338810<br>339300<br>338360<br>337860 |                                                     | br, mt                                                             |                                        |                                                | DT                                 |                                              |                       | Transition between and magn. Al <sub>2</sub> O <sub>3</sub> occurrences.                             |
| Inglisville Church<br>21A/14     | 4969040                                                             | 334140                                         | Vein                                                | pi, br                                                             |                                        | Hem                                            | FGLMG                              |                                              |                       | Mineralization occurs within<br>granite-pyroxenite contact.                                          |
| Quartzite Showing<br>21A/14      | 4968220                                                             | 333150                                         |                                                     | mt, pi, br                                                         |                                        | Hem, Ser                                       | OSW                                |                                              | Y                     | Fracture width 2cm and 10cm long.                                                                    |
| Delaney's Brook<br>21A/14        | 5) 4973520<br>6) 4973360                                            | 337320<br>337310                               | Vein                                                | py, ps, sp, mt                                                     |                                        |                                                | COH                                |                                              |                       |                                                                                                      |
| Nichols Dam<br>21A/14            | 4968330                                                             | 330960                                         | Vein                                                | py, ps, sp<br>(CO <sub>2</sub> , Au)                               |                                        |                                                | White rock                         |                                              |                       |                                                                                                      |
| Scrag Lake Quarrenous<br>21A/15  | 4) 4957400<br>48) 4963410<br>4) 4961890<br>4) 4961840<br>4) 4959570 | 344950<br>342050<br>342900<br>343820<br>349570 | Quarzen<br>Quarzen<br>Quarzen<br>Quarzen<br>Quarzen | as, py, sp<br>as, sp, br, py<br>py, mt<br>py, mt, sp, br<br>as, ps | qr, tr<br>qt<br>qr, tr<br>qr, tr<br>qt | ma-Gr<br>ma-Gr, Hem<br>ma-Gr<br>ma-Gr<br>ma-Gr | BMG<br>MBMG<br>FGLMG<br>BMG<br>BMG | 158-83 E<br>162-90 E<br>164-96 W<br>158-45 E |                       | Vein width 1-2cm<br>Veneers width < 1cm<br>Vein width < 1cm. Close to DCmgSG.<br>Vein width < 1-2cm. |
| Closed Lake<br>21A/15            | 4968640                                                             | 351250                                         | Breccia                                             | pi, mt                                                             | qr, fl                                 |                                                | BMG                                |                                              |                       | No outcrop, brecciated boulders.                                                                     |
| Randall Lake<br>21A/15           | 10) 4974400<br>11) 4972320                                          | 358100<br>357730                               |                                                     | pi, mt                                                             | qr                                     | Hem                                            | COH<br>BMG                         |                                              |                       | Micro-granite boulders 5% COH.                                                                       |
| Dalhousie road<br>21A/15         | 4) 4967450<br>5) 4958280                                            | 366080<br>366690                               |                                                     | mt                                                                 |                                        | Hem, Lm                                        | FGLMG                              |                                              | 0.51-54 W             | Crystalline mineral occurs at the contact<br>with the DCmgED.                                        |
| Nichols Page Lake<br>21A/15      | 4962300                                                             | 366520                                         |                                                     | mt, br                                                             |                                        | Hem, Bv                                        | BGD                                |                                              | 0.59-87 S<br>172-78 W | Mineralization occurs between the<br>intersecting thrust zones.                                      |

| Name, Map Sheet and Number             | Northing                      | Easting                    | Type      | Ore Minerals<br>[elements in brackets] | Gangue    | Alteration            | Host<br>Rock | Qz<br>Veins | Fract.<br>Shear | Comments                                                       |
|----------------------------------------|-------------------------------|----------------------------|-----------|----------------------------------------|-----------|-----------------------|--------------|-------------|-----------------|----------------------------------------------------------------|
| South of Kelsey Lake<br>21A/15         | 4961200                       | 369840                     |           |                                        | qtz       | Hem                   | FGLMG        | 201.52 W    |                 |                                                                |
| Kerry Lake Occurrence<br>21A/12        | 4960970                       | 370160                     | Graben    | an, py, ap, m                          | qtz       | ma-Gro                | BMG          | 165.89 W    |                 | Vein widths, 1-2 cm, spaced at 25 m.                           |
| Gasperum Lake<br>21A/12                | 4975800                       | 376420                     |           | an, so, ka, Limonite                   | qtz, fl   | ma-Gro                | MLG          |             |                 |                                                                |
| Aylesford Lake Occurrence<br>21A/15    | 4977410                       | 376800                     | Graben    | an, ap, py                             | qtz, fl   | Hem, Lim,<br>Gro, Alb | MLG          |             | 055             |                                                                |
| Nature Torbrook Area<br>21A/12         | 4974600<br>4977100<br>4977620 | 344780<br>347000<br>345440 |           | bc                                     |           |                       | DT           |             |                 | Minerals Qz, act in narrow beds inter-<br>layered with slates. |
| Mariestown<br>21A/15                   | 4981150                       | 369820                     | Vein      | monazite minerals                      |           |                       | COH          |             |                 |                                                                |
| Torbrook<br>21A/15                     | 4973670                       | 350220                     |           | an, bc                                 |           |                       | FGLMG        |             |                 | Deposit occurs along fracture of DCMG.                         |
| Nicholsville<br>21A/15                 | 4981600                       | 355120                     |           | pyroxene                               |           |                       | GSW          |             |                 |                                                                |
| Pow-prim Showing<br>21A/15             | 4960960<br>4960680<br>4960300 | 417810<br>417800<br>418250 | Vein      | wo                                     | qtz       |                       | CGLMG        |             |                 | Vein widths, 3-9 cm, occur over a width<br>of 9m.              |
| Black Brook Doodwaters<br>21A/15       | 4960390                       | 418950                     | Vein      | wo, sh                                 | qtz       |                       | CGLMG        |             |                 | Vein widths, 5mm. Close to contact with<br>the DC mgst.        |
| West of Little Pine Lake<br>21A/15     | 4964100                       | 417120                     | Pegmatite | wo                                     |           |                       | BGD          |             |                 |                                                                |
| North of Little Pine Lake<br>21A/15    | 4965800                       | 405100                     |           | Py, sh                                 | tr, qz    | ma-Gro<br>Gro         | BGD          |             |                 |                                                                |
| Western Shore of Parake Lake<br>21A/15 | 4964350                       | 412750                     |           | ma                                     | qtz, K-Sp |                       | BGD          |             |                 |                                                                |

[illegible]





